INDUSTRIAL RESEARCH

SUMMER, 1959

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THE MANAGEMENT MAGAZINE OF TECHNICAL PROGRESS

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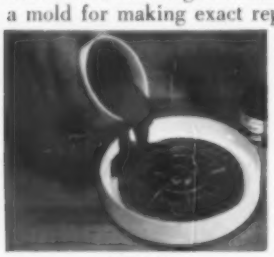

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SUMMER, 1959

INDUSTRIAL RESEARCH

UNDERWATER *is not only an exotic laboratory of ichthyologists, but also the new medium for some very practical industrial researching. Applications of new devices being developed by the* Underwater Water Manipulators *(article starting on page 12) include keeping waterways ice-free in winter, aerating ponds and lakes, controlling waves, communicating through water, mining the ocean-bottom, propelling personal submarines, and even harnessing the electrical potential of the seas. The cover shows water manipulator Donald Johnson using milk for a dye to test a new "aqua-therm" aerator. The device shafts a "pipeless pipe" of water horizontally to create a wide area of water aeration.*

underwater water manipulators 12
by Neil P. Ruzic, editor

the world's hottest alloys 20
by Harry B. Goodwin, metallurgy consultant, Battelle Memorial Institute

tomorrow's light is here 28
by Dr. Henry F. Ivey, manager of phosphor research, Westinghouse Electric Corp.

is there really a shortage of engineers? 76
by Earl C. Kubicek, director of alumni placement, Illinois Institute of Technology

the flying machine: a new era (part 3: tomorrow's spacecraft) 82
by K. M. Wylie Jr., contributing editor

blue-sky profits 44
by Theodore Berland, contributing editor

research business vs. research institutes 52
I—pro-profit: *by Dr. Roger W. Truesdail, president of Truesdail Laboratories Inc.*
II—pro-non-profit: *by Dr. Clark A. Dunn, director of engineering research, Oklahoma State University*

the Martin co's wellspring of ideas . . . 62
by Welcome W. Bender, director, The Research Institute for Advanced Studies

our non-scientific government 68
by Dr. Joseph W. Still, contributing editor

Upcoming

The Automation Controversy

Space Technology *(special section)*

Revolution in Automobiles

The World's Hottest Alloys *(conclusion)*

Can Research Save the Railroads?

Microminiature Components

Desalting Water for Industry

letters to the editor 8

three—notes on the third issue 8

the research trendletter 37

military R & D 91

books of the quarter 93

Industrial Research magazine is published to help management men and engineers keep informed of the profitable applications of research in all fields of industry. Its goal is to help place research on a par with other management functions, such as sales, finance, production, and engineering, and—by doing this —to help reduce the time lag between invention and production.

INDUSTRIAL RESEARCH

the new management magazine

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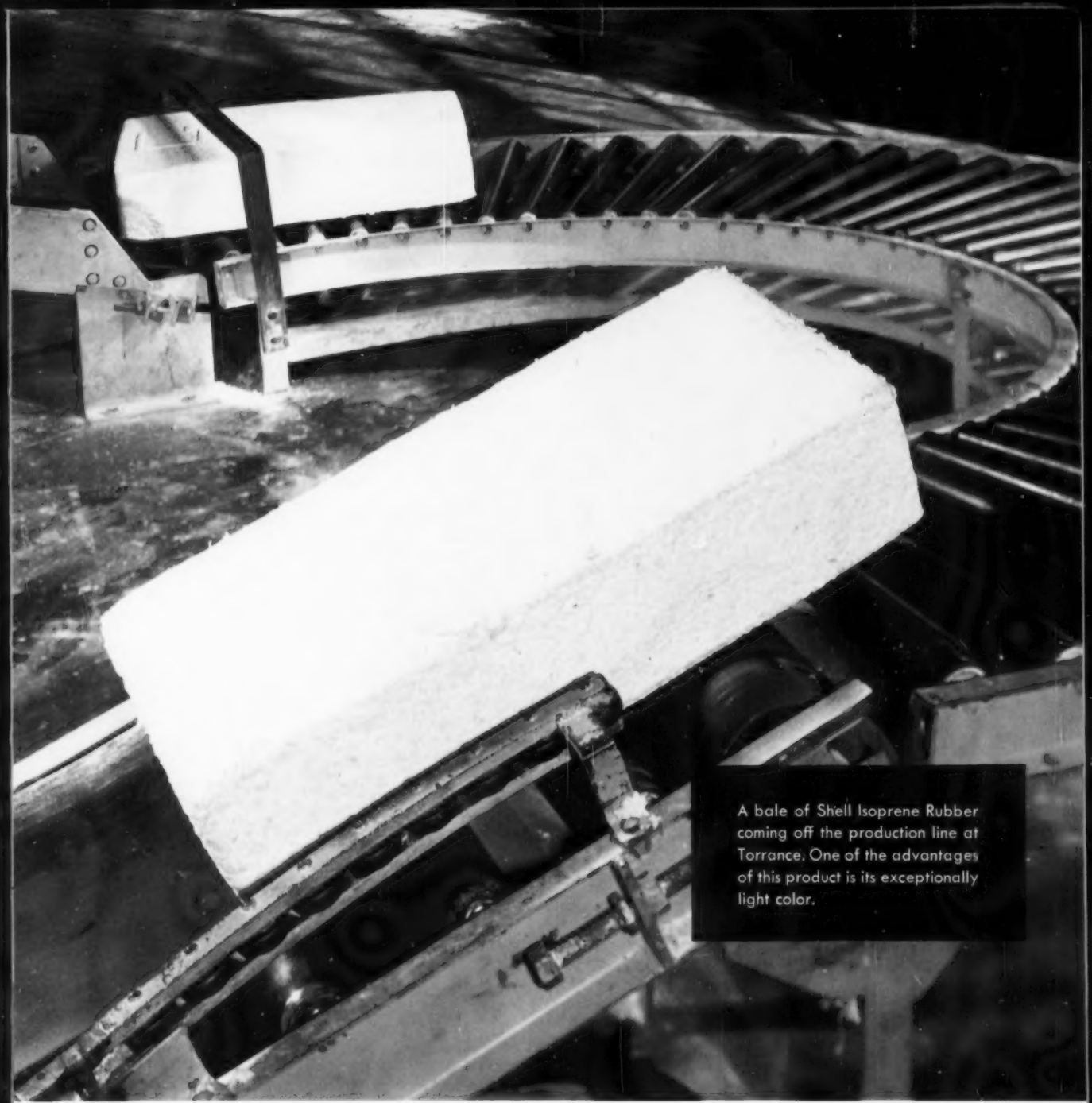

A bale of Shell Isoprene Rubber coming off the production line at Torrance. One of the advantages of this product is its exceptionally light color.

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I•R LETTERS TO THE EDITOR

Long-range automata

Sir:

From a money-making point of view your article *Automata* demonstrates the very long-range kind of thinking necessary for today's technical management.

In the matured industries, buyers are too often plagued with a short-sighted price shopping that pressures manufacturers to divert creative engineering talent from blue-sky research and development to comparatively mundane cost-cutting projects.

For example, no sooner had we given our R&D team a green light for a starry-eyed development project than the sales force reported an increasing number of orders being lost on price alone. Our engineers told us they could have saved many of these orders if we had put them to work shaving costs.

This illustrates the dilemma: which direction should we have pointed our qualified research people? There are never enough of them to do everything we can dream up. This is a persistent gnawing problem.

Our R&D budget is focusing on advancing the art by introducing new practices through new products. Our 1958 R&D budget was 20% greater than 1957's, and this year's budget will be 15% greater than 1958's.

These research expenditures should create products that we expect will increase our business 50% during the next few years. These are more than hollow statistics; they are our jobs tomorrow.

John Conrad, president
S & C Electric Co.

Short-range subception

Sir:

According to D. H. Radler's definition of subcep-

3

Notes about the third issue

The underwater scene on the cover of this I•R, as well as many of the wet views on pages 12 through 16, were taken by Jim Thorne, founder of Adventure Inc., Chicago.

A member of the famous Adventurers Club, Thorne has wrestled shark, giant sea turtles, and barracuda in pursuit of still and motion pictures all over the world. Thorne's ocean-bottom activities now include an "Adventure Products" phase, described more fully in the underwater story beginning on page 12.

tion (*Subception, or Deception?*, Spring, 1959 I•R), everyone is influenced by this sort of stimulus. The trouble is that it is not understood.

You can not create smooth, unconscious forces with sharp flicker images unless you get perfect resonance. But every good writer creates unconscious subceptive forces by the sequences of his ideas.

When this process is understood as scientifically as it is intuitively, the ideas of James Vicary will be seen as the first flash of lightning in advance of a new kind of communication power.

Gorden Speedie
Gorden Speedie
Advertising

Sir:

Your article on subliminal perception certainly hit the nail on the thumb by combining it with deception. This article should relegate it to the flying saucer folklore.

Joseph S. Scott
Plant Manager
Burton Mfg. Corp.

Decision making

Sir:

The *Business Decision Making* article in your Spring issue gives the impression that many—too many—executives do not make individual decisions. If this is true of management (and it probably is of most management), it is not true of labor; Hoffa, for instance, never delegated a decision. The decline of American industry may be at hand.

Lewis Asher
Vice-President
The Wicklander Co.

Sir:

Decision making is a lonely task, but a vital one. The fact that many executives "committee" that task to death is not all bad news. Bright junior executives often find their ways to those committees, discover the latent fallacy in them, and (a few) turn themselves into dynamic executives of the next generation. This may be idiotic methodology, but it is industry's life cycle.

Richard S. Pearson
Chief Engineer
The Burndig Corp.

Honest silicone

Sir:

My compliments on your very fine *Nitrile Silicone Rubber* article. In my way of thinking and to

Thorne

Palm

Felix Palm, artist of the electroluminescence scene on page 28 and of the controversial view of the university research laboratory on pages 58–59, this issue, directs the six-man Felix Palm & Assoc. studio in Chicago.

many others in this department, this is one of the most straight-forward and honest appraisals of the material that has appeared to date.

Robert S. Argyle
Manager, Advertising
Dow Corning Corp.

An unmotivated technical mind

Sir:

I have a technical mind which resents artificial motivation. It is just possible that executives can get their best engineering team effort not by listening to Dr. Dichter (*Motivating the Technical Mind*, Spring I•R), but by taking a more sincere personal interest in their technical staffs.

Webster A. Bonewell
U. S. Steel

Opinions on 2nd issue

Sir:

Commending a publication on its merits has never occurred to me before, but the several issues of I•R received have left me so favorably impressed that I feel the staff of I•R rates the heartiest congratulations for publishing such a fine magazine.

The ability to produce such informative articles on so many varied types of industry is a very commendable achievement. My hat's off to you, and I look forward to receiving future issues of your magazine.

E. O. Hawkins
Chairman of the Board
Orleans Materials & Equipment Co.

Sir:

As former managing editor of *Scientific American*, former editor of *Popular Science Monthly*, and former editor of sundry trade and technical journals, I appreciate good editorial contents. Your efforts set a new mark in technical journalism. Keep up the high calibre of your efforts!

Dr. Austin C. Lescarboura
Lescarboura Adv. Inc.

Sir:

I was astonished at the range of subjects, the competence of the writers, and presentation of topics and information. It was a reflection of a need in a publication that I, for one, could never put my finger on, until I saw it.

At last there is a magazine which covers new

Palm, who "specializes in nothing," exhibits his versatility with water color, oil, chalk, and other mediums suitable in the graphic arts. He also does about 300 portraits a year, mostly of children, and in this pursuit has illustrated a children's bible story book published by Grosset & Dunlap.

Aside from art, Palm designs house and office interiors, is a photographer, and holds several patents in packaging and construction.

No . . . of course minus gravity doesn't bother me.

ideas and materials, developments of all kinds, administration problems, and business psychology that I can read and understand without having to be a specialist in each.

Industrial Research can help produce in its readers an overall perspective in business as a whole instead of a half-inch-thick slice out of a 28-inch watermelon.

Russell Shoup
Insulation Mfgrs. Corp.

Sir:

I want to compliment you on the handsome and intelligent handling you have given *Industrial Research.*

William L. Banning
Account Supervisor
Reach, McClinton & Co.

Sir:

It is a pleasure to have my husband bring home a technical magazine from which I am able to extract some interesting information other than how to de-energize a valve when trouble occurs. *Industrial Research* has opened a new field of communication.

Stephany Rose
wife & mother

Sir:

Just a note to congratulate you on an extra fine publication put together as anyone can see by professional technical and literary people. I•R is the first and only professional publication I've consented to pay for, since the majority of them are free.

Frank X. Fay

Sir:

It is an exciting thing to see such a magazine as I•R enter the industrial field. If the bane, and the joy, of our existences, the industrial advertiser, only has enough sense to recognize a damn good idea when he sees one, you should have no trouble becoming one of the most important publications in the U.S.

Peter Maxwell, editor
Delaware Valley
Announcer

Sir:

The format of I•R is excellent and the contents very stimulating and packed with interest. We have needed a publication such as *Industrial Research.*

A. Wassermann
American Potash & Chemical Corp.

New in issue No. 3 is a column on Military R&D, written by I•R's Washington Bureau chief, Murray Queen Smith.

■

This issue's special section—on Basic Research—says some of the less obvious things about the "long-hair" pursuit.

It says, for instance, that money has been made and can be made through basic research (Blue-Sky Profits—page 45); that even a single-product firm like the Martin Co. (missiles) should and does perform basic work in unrelated areas (the Martin Co.'s Wellspring of Ideas—page 62); and that this greatest of all scientific nations exists under a science-less handicap (Our Non-Scientific Government—page 68).

It also portrays both sides of a vital but behind-the-scenes controversy: who should conduct basic research? (Research Business Versus Research Institutes—page 52).

In the next issue, Fall, Industrial Research will present a special section on Space Technology. Underlying theme will be that a very big industry has been created in the past few years around a future product of hope and probabilities.

Industrial Research

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CITY ZONE STATE

Underwater Water Manipulators

2

1

by **Neil P. Ruzic,** *editor, Industrial Research*

3

4

1. *A "pipeless pipe" of milk-dyed water shafts 30 feet to the surface in an aqua-therm experiment. Diameter of the shaft starts at 22 in. at bottom, measures only 30 in. at 24 ft.*

2. *The inventor George Gross (right) and underwater photographer Jim Thorne assemble equipment at Rainbow Springs, Fla.*

3. *Johnson's pier, at Lake Geneva, Wisc., sits in a pool of liquid water—in 20 below weather.*

4. *The aqua-therm, basic to most of Gross' developments, transposes warmer bottom water to colder surface water, thereby preventing freezing.*

A VAST AREA some 47 times larger than the United States exists on earth. Comparatively, it's unused, unexplored. Economically, it's vital to the continued development of this planet. Potentially, it's accessible—much more so than anything in space.

Yet, in reality its atmosphere turns to solid rock in the most important areas during parts of every year. And even where it remains fluid, the "atmosphere" is as unbreathable as the moon's vacuum; its gravity as light as Mars'; its pressure as heavy as Jupiter's.

It is, of course, the 140 million square miles of terrestrial real estate covered with water and ice.

Underwater manipulation, like "planetary" engineering of science fiction, takes place in a completely alien environment, has problems unlike anything on earth, and is rapidly coming up with a whole series of new products and answers for several hitherto neglected markets.

Probably the most significant answer provided by underwater manipulators is to the question, how to keep water liquid in sub-freezing winter at an economically justifiable cost. The problem not only plagues such developments at the $1 billion St. Lawrence Seaway, but also thousands of harbors, small lakes, rivers, channels, and livestock ponds throughout the northern hemisphere. Year-around water commerce is part of the promise. But also significant is the growing use of small lakes, lagoons, and rivers for commercial and pleasure fishing and for aqua sports.

Liquid water—at 20 below

Underwater researchers not only have found out how to keep water from freezing economically—even cheaply—in 20 to 30 below zero weather, but also are developing new piers, aerators, wave control methods, propellers, underwater tools, protection devices, submarine conveyances, and through-the-water "telephones."

These are the engineering developments that must supplement scientific findings if the new underwater technology is to progress. For the first time *en masse*, and largely as a result of IGY explorations, scientists are looking to the seas to solve problems now becoming unsolvable on land or on the water's surface:

- New sources of oil, manganese, cobalt, copper, gold, and other resources.
- Water transportation impervious to storms.
- Undetectable military installations.
- Unlimited (by acreage) farms for both crops and seastock.

The potential is as vast as the imagination.

The story of underwater manipulation is largely the story of a single group of Chicago researchers. It had its beginnings only a few years ago in the mind of George E. Gross, then employed in Armour Research Foundation's department of mechanical engineering.

Among other duties, George was safety engineer for research weapons testing at facilities in and near Chicago. This was a role that grew out of his wartime experience in Army Ordnance with rockets, explosives, and fuzes. Later it played an important part in underwater detonation experiments.

In spare time Gross was a gadgeteer, following the insights of his problem-solving ability rather than the academic approach of his degree in industrial engineering. When his friend, Herbert J. Johnson, a concrete and swimming pool contractor in Skokie, Ill., told him of his pier problem in Lake Geneva, Wis., Gross had an idea.

Johnson's pier, an elaborate installation built to hoist a half-dozen speedboats, would cost $1,200 to take out in the winter and replace in the spring. Repairs incurred in moving would boost the cost even higher.

"Why remove it?" Gross said.

"Ice."

"Is that the only reason?"

Expensive ice

It was a big reason. It was why thousands like Johnson pay upwards of $400 a year to dismantle their piers; why the fishing industry and all water commerce in the north cease like clockwork with the first freeze; why whole nations are landlocked in winter.

Ice plays havoc with piers and

other water installations. At very low temperatures, expansion alone amounts to as much as 16 inches for every mile of surface ice. Expanding, contracting, cracking, shifting, and floe ice exert 72,000 pounds of pressure per square foot of pier, seawall, or boat house. Anchor ice (ice that forms around objects on the lake floor) clogs inlets to purification and hydroelectric plants—a problem currently solved with dynamite.

Johnson went to Mexico that year, leaving his pier in Gross's care. When he came back in February the pier was still in the water, unharmed. Ice 30 inches thick covered the entire lake—except in a four-foot perimeter around Johnson's pier.

Had Gross heated the water?

No. Water heaters are far too expensive to operate. Gross's device, a heat pump, literally lifted the warmer water lying at the bottom of the lake and deposited it on top. Today, his improved models can do this with a few electric motor-power units of less than 1/55th-horsepower each, at an operating cost of two cents a day per unit, or a couple of dollars for the whole season.

Two phenomena made the invention called "Aqua-Therm" (patent pending) possible:

- Water at the bottom of a lake is usually *above* 34° F, even when the air temperature is 30 to 40 *below* zero.
- Warm dense water does not naturally mix with cold light water in a lake. Instead, the two kinds of water lay in separate strata, the cold on top of the warm, like oil over water.

Moving water through water

Water researchers had known these things for years, yet had been unable to reverse the strata conveniently, to place the warm water on top. Why? Because they did not know how to move the only-slightly-warmer water along the bottom through the middle layers without mixing.

Basic to Gross' device is its ability to jet the warmer water through the middle layers and remain unaffected by them.

The first aqua-therm consisted of a long horseshoe-like pipe punctured at calculated distances and extending two-thirds the way around the pier. It rested on the bottom with the holes pointing upward, jetting water in scores of tiny columns. A 250-foot length of downspout pythoned out into the lake, seeking deeper, warmer water. The motor unit, at the center of the horseshoe, acted as a heat pump, drawing comparative heat out of the downspout and also out of the earth itself.

The warm water is driven to the top without becoming diluted on the way up. On the surface, as it tends to freeze, it's replaced with a new layer of warm water. The cycle need not be 100% continuous even in the coldest weather.

Taking the ideal condition for the area—that is, water temperature as the maximum available and full-time operation as 100% efficiency—then the percentage of actual running time, multiplied by the percentage of the maximum water temperature gradient available, yields the operating efficiency of the unit. At 15° below zero, an efficiency of 38% is sufficient to keep ice from forming—provided the on-off cycle is controlled correctly. In practice, this means the aqua-therm need run only about 50% of the time in 15° below weather.

The first aqua-therm was an unwieldy monster compared to today's models. From experiments at Johnson's pier, Gross, William F. Cramer Jr., an Armour senior engineer, and Donald Johnson, son of Herbert Johnson, advanced to far simpler models. Gross left Armour to form a company called Perma-Pier Inc. At the same time, he formed another (not-for-profit) firm, Future Products Research Inc., to research the expanding ideas.

'Pipeless' piping

First on the list was an aqua-therm that would work without the cumbersome, expensive piping. Gross and Cramer reasoned that if the pump housing were designed correctly, it could tap heat from a lower, warmer layer and eliminate need for the 250-foot downspout. They also felt that a stronger pump could jet a large enough shaft of warm water to make the horseshoe piping unnecessary.

The first theory was correct; the second was not. Water from the many small pipe jets somehow arrived at the top without diluting its warmness in the middle layers. But a single large stream of water direct from the pump didn't do this.

To find out what was happening they needed a dye, an inexpensive, harmless dye. A dye with the same specific gravity as water. Milk. The milk showed the "pipeless pump" merely resulted in a general upflow of water that dispersed and mixed with the cooler water in an ever-widening cone toward the top. The pipe jets, on the other hand, streamed tiny shafts of milk-water that remained undiluted.

The invention that hurdled this obstacle came before the theory that explained it. The water researchers were testing the system last winter in Crystal River and Rainbow Springs, Fla. Gross, while in the boat and with only a pair of pliers, fashioned a new-type propeller for the pump motor. Then he skin-dove to the aqua-therm, installed it, poured in the milk-dye, and turned on the motor. A shaft of milk-whitened water started with a four-inch diameter, quickly expanded to about 18 inches, and *stayed at 18 inches* on its 30-foot climb to the top!

When properly adjusted, the shaft of water mushrooms when it gets to within 16 inches of the surface. It covers an area 30 feet in diameter, depositing the warmer bottom waters into the necessary oil-like surface layer that prevents freezing. Diagonal shafting, they found—and multiple shafting, using one pump oscillating on a ball and socket to form several streams of water—results in even wider surface coverage.

After inventor Gross made the shaft work, scientist Cramer explained why. His explanations were mathematical and continuous, leading to additional refinements for varied conditions. Generally, Cramer found, the

'Pipless piping' and aqua-

FIRST AQUA-THERMS *were accompanied by hundreds of feet of pipe, here held by Donald Johnson, left, and Jim Thorne, and shown (in far right photo) surrounding a pier installation near the bottom of a lake. The wedge shape at top left of right-hand photo is ice —successfully absent from vicinity of pier.*

propeller slows down the velocity of water in the middle of the shaft and increases it on the outside, thus forming a "pipe" of water through water. But exactly how the propeller achieves this, plus its design, are secret pending further development.

Since that breakthrough, the water manipulators have devised a number of propellers and horsepower ratios that can yield the desired water jetting and mushrooming effect anywhere from 10 to 40 feet deep. They also have miniaturized the aqua-therm into compact, 1/55th-hp-motor pumps encased in heavy steel shells for shallow depths.

The St. Lawrence in winter

With these developments the possibility of keeping the 27-foot deep St. Lawrence Seaway open throughout all or part of the winter became evident. In spite of low operating cost, the expense of piping the whole seaway would have been prohibitive.

But with "pipeless piping," larger aqua-therms could be dropped along the entire length of the seaway at an estimated five-year material depreciation cost of $7,200 per mile of open channel per year. Along the northernmost parts of the seaway, a combination of aqua-therms and some external heat-producing method, possibly radioisotopes, might be necessary during coldest periods.

Since channels in harbors and rivers can be kept open with widespread use of aqua-therms, boats would not have to be taken out of the water in winter. The devices will last at least five to seven years. If they malfunction they're cheaper to replace than repair.

An offshoot of the "pipeless aqua-therm" is the "pipeless aerator." It is simply an aqua-therm outfitted with a snorkel to draw air from above, and a venturi (a neck-down nozzle), through which the air would pass and be broken into fine bubbles. The device creates a steady noise, "like a V-2 taking off," says Gross. The noise vibrations, which were recorded on tape, attract fish, incidentally. The bubbles of air keep them attracted.

Killing 'winter kill'

Use of the pipeless aqua-therm, in addition to keeping lakes and harbors open in winter, would help solve the multi-million-dollar scourge of fish farmers, sportsmen, and hatcheries—"winter kill." If winter kill could be partly prevented with an aqua-therm, why not use the aerator to completely end winter kill as well as "summer kill?"

These terms describe conditions in which whole fish populations suffocate because of lack of oxygen-bearing air in the water. Winter kill occurs when a blanket of ice prevents air from dissolving in the water. A lack of sunlight intensifies the problem because it causes plants to decay, thus using up what little oxygen remains.

Summer kill, which results from very hot weather and low-wave activity, suffocates fish because warm water holds less oxygen. Yet, Gross knew, the warmer the water the faster fish will grow—provided there is a high degree of oxygen in the water.

Aeration systems are in current use. But these conventional devices use pipe distributors that limit their versatility and increase expense. Gross' unit, utilizing the propeller he invented in place of a venturi, can aerate more than 100,000 cubic feet in about an hour.

The secret of its effectiveness is the smallness of the bubbles and the horizontal flow created by the propeller. In operation, fine bubbles are stripped off the air intakes, emulsified, and driven in a horizontal shaft along the bottom (as shown on the cover with the aid of a carton of milk). Some of the fine bubbles lump together and form larger bubbles more than 1/64-inch diameter (as shown on page 16). These rise to the surface as a curtain of bubbles within 15 to 20 feet from the unit, creating a vertical circulation pattern. But the most important, dust-sized, bubbles (same photo) continue horizontally, clinging to objects and distributing themselves over a large area.

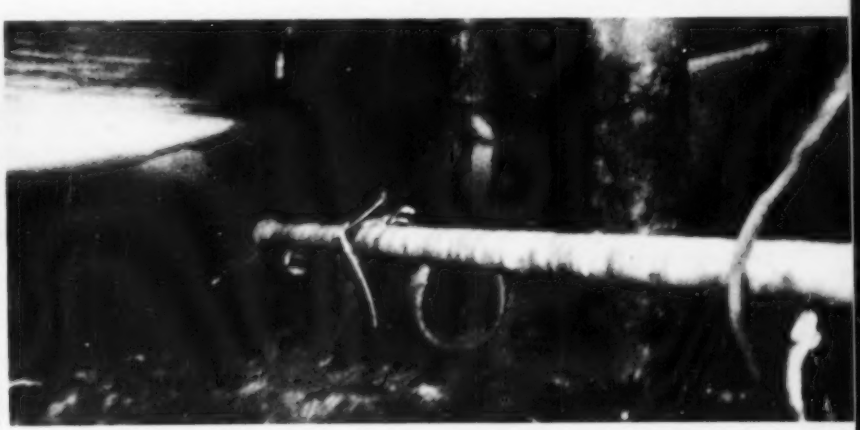
The pipeless aerator can be dropped through a hole in ice to prevent winter kill much more economically than keeping the entire lake from freezing all winter. In summer it can be used during hot weather as required.

Wave control

While experimenting with the aerator, the water manipulators noticed that under certain conditions a perceptible change was made in surface wave patterns. A number of tests were made and a principle—of wave control—established.

Recently the British announced a $6 million bubbler installation at

therms may be the answer to keeping the St. Lawrence Seaway open during winter.



Dover, England to control waves and prevent ship damage in close maneuvering, docking, and mooring. It was true that the bubbles did tend to shorten waves, but the shaft of water from a modified aqua-therm should work much better.

Explains Gross:

"Why use an indirect method (bubbles) when you can do it directly with a shaft of water? It doesn't take much force to knock down a wave if the shaft is aimed in the right place."

Further experiments at Lake Geneva revealed that 18-inch waves on one side of a relatively small aqua-therm were significantly eliminated on the other side. At least three applications immediately leap to mind:

- To prevent shore damage without costly seawalls.
- To eliminate undertows on bathing beaches.
- To facilitate military landing craft—a problem so severe in World War II that hundreds of ships were sunk deliberately just to form breakwaters.

'Ductless' ducting

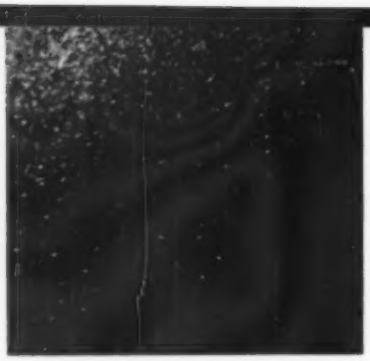
Some interest is beginning to be shown in Gross's new propeller for other applications: to move air, instead of water, in a shaft ("ductless ducting") to save the expense of ductwork on warm-air heating systems; to propel boats rocket-fashion with an efficient, high-thrust stream of water.

The success of the propeller and the pipeless aqua-therm also smooths the way for new pier designs. For instance, the Fibrecrete Corp., Long Beach, Calif., has a modern economical floating pier, which because of its light concrete construction would have difficulty in northern climates during winter.

Gross and his Perma-Pier company want to enter the pier business too. They have ideas for piers that would work on large lakes or in the Arctic, piers that will be protected not only from "static" ice, but also floe ice.

Another pier they plan would cantilever out from center posts for easier hoisting of boats, safer slides for children, and a more modern appearance. Such designs have not been popular in the past because, when a pier has to be removed every year, nothing beats the ten-thousand-year-old post pier. Nothing, that is, except the aqua-therm.

That the aqua-therm really works



FINE BUBBLES *are the secret of successful aeration. The large bubbles travel upward from Gross' "emulsifier," but fine, dust-sized ones go horizontally to set up a cycle of aeration. The pipeless aerator could be dropped through a hole in ice to prevent winter kill. Below, sheets of air-preventing ice are shown from underneath.*

under actual commercial conditions has been proven several times. The Rahr Malting Co., in Manitowoc, Wisc., wanted an aqua-therm to thaw a 30-inch crust of ice on one of its ponds. The underwater engineers, working through their Perma-Pier corporation, designed a unit for the job and shipped it with instructions to cut a hole in the ice, drop it in, wait two days, and observe a 20-foot clearing.

The Rahr Co.'s trial of the unit was also its first test. In two days, a 20-foot liquid crater appeared in the ice.

Similar successes resulted in a flood of orders—most of which remain unfilled for two reasons. Last February, Herbert Johnson, one of the original trio, was installing a new tile floor in the Perma-Pier office. He had spread mastic over the entire floor and was laying the first tile when the flame from a gas hot-water heater ignited the mastic fumes. The building went up in flames instantly. Johnson was burned to death.

Johnson's death and the loss of the office building was a business as well as a deep personal tragedy that set the researchers back several months. Fortunately, Johnson's son, Don, was able to take over his father's interest in the corporation. Fortunately, also, they were also able to rebuild the workshop-research laboratory, and now have a complete shop with large testing tanks.

The other reason for the backlog of unfilled orders is that every new accomplishment begets new information, new processes, and new patent applications — the excitement of research.

Skin divers: 11 million of them

There is another excitement in this business also. Gross and his partners had taken up skin diving as a necessity, but it quickly became an area for discovery and invention itself. Swimming, walking, working, breathing take on new meaning underwater. There is weightlessness. There is fantasy, drama, and adventure.

There are also 11 million other skin diving Americans comprising a mass, relatively untouched, market.

Jim Thorne, a member of the famed Adventurer's Club and co-owner of an underwater photography group called Adventure Inc., arrived on the scene, first to photograph the cover and other pictures for I•R, later to join the research. Thorne and Gross formed a third company, Adventure Products Inc., to produce and license a host of gadgets from variable-weight belts to submarine "flying belts."

Underwater vacum cleaner

Nor do the applications of Gross' water manipulators end here. Like Lorenzo Jones, Gross has developed an outdoor vacuum cleaner—except that the Gross cleaner goes underwater. The vacuum cleaner pulls silt, seaweed, and water through the system, but deposits heavy particles—such as lost jewelry, archaeological objects, etc.—gently into a basket.

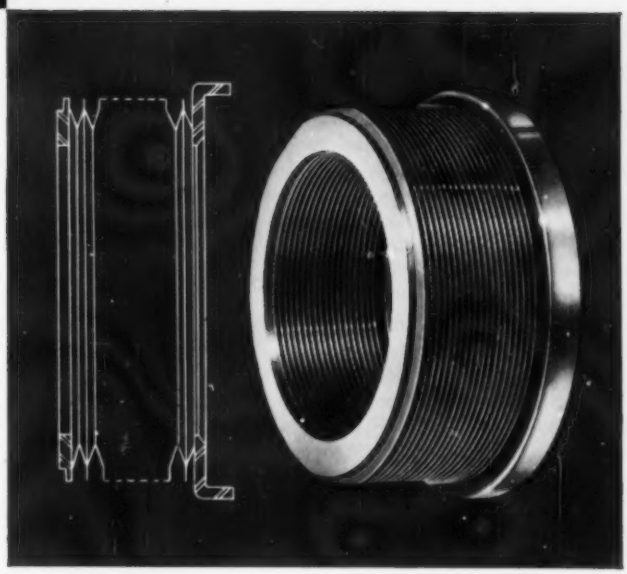
Like the large, cumbersome conventional suction systems, the "vacuum cleaner" can be used to build up beaches (by depositing sand from deeper water), keep river and channels free of debris, and undercut large objects buried in the bottom. But the new device has the advantage of being small, easily portable, versatile, and far more economical.

Ever try to shovel a hole in the ground underwater? Simply by using a small unit outfitted with a special propeller, you can unbury a treasure,

(continued on page 18)

C/R DESIGN NOTES

How C/R's New Metal Bellows Seal Meets Seemingly Impossible Operating Conditions



Operating Ranges

Temperature	−400° to 1000° F.
Pressure	500 psi
R.P.M.	80,000 plus

These known operating ranges indicate the function of this seal. It is designed for applications where temperatures and mediums to be sealed forbid the use of any organic materials. Typically, these applications include fuel pumps, compressor power units and turbine starters characteristic in rockets and missiles. Other applications include mechanisms which are exposed to a high level of radioactivity.

Design Advantages

The C/R metal bellows seal consists of a metal bellows — a welded homogeneous unit which is secured at one end — and a carrier ring in which the sealing face is mounted. The seal does not contact the shaft. It is stationary, and the only rubbing surfaces are the sealing face and mating ring. These surfaces are precision lapped to provide a positive seal with minimum friction. At any given pressure, the seal can be designed to maintain proper and constantly effective face loads. It orients immediately to run-out and will resist any torques it is subjected to in operation. The design has high end-play tolerance: Chicago Rawhide engineers have deflected a bellows .100 in. for three million cycles at 1750 cpm and at a temperature of 500° F. with no adverse effects.

A further advantage is relatively light weight and compactness. The C/R metal bellows seal can be designed for minimum axial and radial space. Axially, complete seals can be produced within a ¼ in. cross-section. Radially, dimensions are comparable with conventional end face seals.

The C/R metal bellows seal can also be designed with an extremely low coefficient of expansion. The importance of this factor becomes apparent with the fact that in many applications the operating temperature may change hundreds of degrees in a very few seconds.

Mediums To Be Sealed

Virtually any known liquid or gas may be positively sealed with this design, depending upon duration or service life. From a practical viewpoint, the C/R metal bellows seal is the best design for the sealing of cryogenic and high-energy fuels such as LOX, hydrogen peroxide, fluorine and other missile and rocket propellants.

Where possible, lubrication of the two sealing faces is desirable to prolong service life. However, the medium being sealed commonly acts as the lubricant and may be merely hot gas.

Materials

Sealing faces and mating rings for the C/R metal bellows seal are available in a variety of materials including carbons, carbides, ceramics and various alloyed metals for both high temperature and corrosion resistance. The bellows can be furnished in any of several metals and alloys such as stainless steel, Monel, Inconel X, Ni-Span C and other special alloy steels.

Consult C/R Engineers

Each application for the C/R metal bellows seal is essentially a custom-design and an intimate knowledge of all conditions to be encountered must be known by Chicago Rawhide engineers to produce the correct combination of properties in the seal. Then, whether you require five, fifty or five thousand seals, Chicago Rawhide will design and produce the correct seal to solve your problem.

Helpful Design Data:

We will gladly furnish you with a design guide and space envelope data concerning the C/R Metal Bellows Seal. Just write for Bulletin MBS-1 on your company letterhead.

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1295 Elston Avenue • Chicago 22, Illinois

Offices in 55 principal cities

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Export Sales: Geon International Corp., Great Neck, New York

For additional information, circle No. 4 on the Readers Service Card, page 101.

survey for minerals, jet posts, or perform a variety of construction feats—all in perfect visibility because the "pipeless pipe" jetstreams away the silt.

It is certainly less fantastic, more economical, and easier to imagine neoprene-sheathed, air-masked farmers harvesting their crops with an Adventure Products "aqua-plow" than it is a bubble-domed spaceman growing anything on near-airless Mars. Both the French and the Japanese now grow crops underwater, without benefit of specialized tools.

It's also fairly easy to visualize use of these tools in the coming mining of undersea minerals. One survey, by University of California scientists, estimates that loose-lying metal-bearing rocks are worth $1½ million per square mile in some areas. Scientists at Plymouth, England have found appreciable quantities of the strategic niobium and vanadium in the flesh and blood of ascidians, sea animals similar to skates.

Increased exploration undoubtedly will result in similar industrially important findings. For instance, there's no reason to believe that undersea oil deposits are limited to the continental shelf. Most of the new underwater equipment can be remotely controlled and observed from the surface by closed-circuit TV.

Waterbelts and waterphones

With explorers, scientists, farmers, miners, and oil men going more and more underwater, Gross & companies have turned their attention toward other devices. One is a "flying belt," intended to replace the unwieldy, uncomfortable, underwater "torpedoes" now in use.

Another device is expected to do for subsurface communications what the "belt" will do for transportation. The engineers have been experimenting with an underwater wireless sonar-type "telephone."

"After all," simplifies Gross, "air and water are both fluids. The only difference is that water is noncompressible. A good diver can talk underwater by taking the mouthpiece out of his mouth, but it's too difficult for most people and your range is limited. You have to be right next to each other."

The sonar microphone has a range of about 50 feet; it needs further development.

Today, the 'Adventure-Dart'

But an underwater protective device, Adventure Products' patent-pending "Adventure-Dart," is almost ready to go, and is slated to hit the 11-million-man skin diving market later this summer. The aqua-dart, a product of Gross' ordnance experience, is made of waterproof paper with a slow burning propellant and a variety of charges in the "warhead." One type has a deflagrating (non-exploding) charge for deterring dangerous sharks or barracuda in an emergency, or for blasting a hole through ice from underneath. In one experiment, the researchers blew a hole 3½ feet in diameter through 30 inches of ice from an underwater distance of 20 feet. The deflagration did not injure the diver's ears; in fact, it was difficult to hear at that distance.

Other types contain deflagrating charges only. Water being noncompressible, these darts can be ignited and held in the hand with complete safety. Since fish are more sensitive than men to low-frequency sound vibrations, which are produced by the darts, the darts can be hand-held to ward off fish without harming them.

In operation, the dart is triggered, aimed, and released. It looks like a little torpedo traveling through the water at a stable 7½ feet per second. When it reaches its destination—a set 10 seconds and 75 feet later—it goes off into a bright ball of flame. If a diver wants to shoot something less than 75 feet away, he merely estimates the distance and holds the burning dart for the required balance of seconds.

The engineers feel the dart also will be used in undersea target games, since aim and distance depend upon the diver's skill.

Underwater manipulation, though heavily invested in necessary gadgetry in the beginning, also may make significant scientific contributions as the research continues. During one diving session, while Gross and Cramer were working out a thermostatic control for an aqua-therm, he noticed his voltmeter registered a charge when the leads were hanging in the water.

As every demolition engineer knows, a fickle kind of electrical variance exists on dry land. Hence the reason why ordnance men tie in all electrical weapon circuits to a common ground or shunt the leads of blasting caps.

THE ADVENTURE DART *(left) can be released by an underwater swimmer to blow a hole in thick ice (right) large enough to climb through.*

Tomorrow, the 'seabattery'

Realizing the voltmeter showed that a difference in electrical potential also exists in water, Gross placed long leads of the voltmeter in strata of different density. There was a difference of 1.4 volts. Even more significant was the fact that there was always a difference of 1.4 volts. Unlike on land, the electrical variance of water seemed to be constant. Thus, it might be utilized.

Gross now pictures powerless as well as pipeless "Aqua-Therms" and aerators, battery-less submarine telephones, and "flying belts" that draw their energy from the water itself—a perfect marriage, like sailboats and wind, or space sails and solar energy.

More research needs to be done, of course. But now more can be done. As Gross replies when someone asks how it is that all these "obvious" things haven't been developed before:

"You can't invent ahead of technology. Skin diving and submersible pumps had to precede water manipulation."

That and thought manipulation, which has to precede all progress. ■

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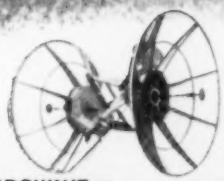
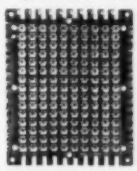
another way to say
"COMMUNICATIONS"



MICROWAVE More reliable and economical in certain areas than conventional wire systems. For telemetering, data and voice transmission, remote control. Dependability better than 99%.



MATRIX Easy-to-position phenolic grid holding up to 10 x 30 miniature selenium disc rectifiers. Ideal for systems requiring translation or logic.

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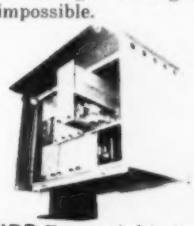

CARRIER Four, eight, twelve, sixteen channels – for telephone, telegraph, or radio multiplex.

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RELAYS • SWITCHES • APPARATUS • TELEPHONES

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For additional information, circle No. 5 on the Readers Service Card, page 101.

Battelle Memorial Institute

Harry B. Goodwin, consultant in the department of metallurgy at Battelle, has participated in a broad spectrum of metallurgical research activities. He has served as coordinator of the institute's molybdenum studies for the Office of Naval Research, the Air Force, and the Atomic Energy Commission; and has been associated with the work of the Titanium Metallurgical Laboratory. Before joining Battelle, Goodwin was associated with the Applied Physics Laboratory, where he helped plan and organize the molybdenum research program and participated in the metallurgical development of ramjets. He is a graduate of Massachusetts Institute of Technology.

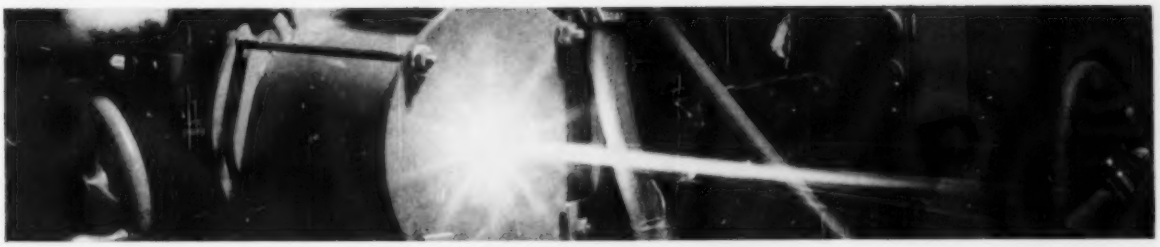
This article is probably the most comprehensive, most easily understood review of the current state of high-temperature 'art' ever written. If your field is nuclear energy, chemistry, ceramics, power generation, engines, aircraft, missiles, space technology, furnaces, heat exchangers, construction, mining, or metallurgy — reading this article could be one of the most profitable hours you ever spent.

PART ONE OF TWO PARTS

AS THE FRONTIERS OF TECHNOLOGY are pushed back, there is an ever more urgent need in many fields for materials that retain useful strength at higher and higher temperatures.

In pursuit of increased thermal efficiency in power generation, top steam temperatures have increased an average of 12 degrees F per year for more than 50 years, and it has been necessary to improve boiler steels continually to permit this increase.

The aircraft gas turbine is another example of the trend toward higher temperatures. Jet-engine-turbine inlet temperatures have increased an average of 15 F per year since 1940, when this type of engine was in a very early stage of development. In advanced



HEAT-RESISTANT ALLOYS AND PLASTICS *are subjected to laboratory ablation similar to that encountered in high-heat flight. An argon-stabilized plasma jet (top), at Battelle Memorial Institute, Ohio, and a mixture of ionized gas and electrons (above), at Stanford Research Institute, California, are being used to heat materials in the 15- to 30,000 F range. The perpendicular lines visible in the lower photo are reflections of the jet nozzle.*

engines, inlet temperatures are now as high as 1750 F and turbine blades (which are probably the most critical components strength-wise) are operating at about 1600 F — about the limit for presently available materials.

For high-performance engines, designers would like to go to turbine inlet temperatures several hundred degrees above those in present engines. To do this, they either must resort to cooling, with its attendant mechanical complications and loss of power, or find materials that will permit the operating temperatures of various components, especially turbine blades, to be increased drastically.

The temperatures to which other aircraft components such as the leading edges of wings may be subjected by aerodynamic heating also become formidable as aircraft speeds increase. For an airplane at 40,000 feet, boundary-layer temperatures will be 250 F at Mach 2 (twice the speed of sound), 640 F at Mach 3, 1150 F at Mach 4, and around 2000 F at Mach 5.

Missiles are another field where "hot" materials are needed. During re-entry into the earth's atmosphere, the nose cone of a ballistic missile may be subject to temperatures of 5000 or 10,000 F and heat fluxes which may exceed a thousand BTUs per square foot per second. While no conceivable material will withstand such temperatures indefinitely, the search is on for materials that will have a

W-2 CHROMALLIZED specimen, left, completely resists oxidation. At right, volatile oxide vapors are given off by untreated piece as it burns away.

CHROMALLIZING
FOR METAL PROTECTION AT JET-HOT TEMPERATURES

Improve oxidation and thermal shock resistance of metals used in jet engines and similar superheat applications with CHROMALLIZING. This patented method of diffusing chromium with other elements into the surface provides an alloy case which is integral with the base metal. It can't peel or flake; the chromium and other elements diffuse uniformly into recesses, pores, cracks and even blind holes.

Alloy	Usual Operating Temperature	Operating Temperature of CHROMALLIZED Alloy
Iron Base (including stainless steels)	1500° F	SA CHROMALLIZED 310 and 321 stainless steels show no failure after 18 hours at 1950° F in an atmosphere containing lead bromide and lead sulfide.
Nickel Base	1800° F	U CHROMALLIZED nickel base alloys are unattacked after 200 hours at 2000° F.
Cobalt Base	1800° F	SAC CHROMALLIZED cobalt base alloys are unattacked after 150 hours at 2200° F.
Molybdenum	Over 2000° F	W-2 CHROMALLIZED molybdenum shows no failure after 400 hours at 2350° F, after 48 minutes at 2800° F, and after one minute at 3400° F.

For technical information write to:

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longer life than presently available materials.

Combustion temperatures up to 6500 F are encountered in chemical rocket propellants. In considering nuclear power plants for space rockets, engineers are talking about developing power at densities on the order of 50 to 100 megawatts (50,000 to 100,000 kw) per cubic foot of reactor. To quote Dr. Robert Bussard (lecturing at University of California's series on space technology): *"This is equivalent to packing Hoover Dam into a steamer trunk, and is only possible because the rocket needn't operate as long as Hoover Dam."*

Temperatures will have to be at least 5000 F to achieve such power densities in heat-exchanger-type nuclear rocket motors using gaseous propellants. Present-day reactors of the type being considered for electric power stations operate at power densities of over 2000 kw per cubic foot — in itself a formidable concentration of power.

The foregoing examples illustrate the general trend toward higher temperatures in today's technology. Many others could be cited. It is safe to say that advances in many of these fields are being held up for lack of materials suitable for higher temperature service.

To meet these requirements, industry and government have been engaged in a research effort of unprecedented magnitude. A vast array of materials have been developed or are under development for service at elevated temperatures.

Metals versus nonmetals

There are two major avenues of high-temperature-materials development. One is the development of materials for unstressed or lightly stressed components not subject to severe shock, in which nonductile materials are satisfactory. Such applications conventionally have utilized ceramic-type materials, and improved ceramics are under development for rocket nozzles, missile nose cones, furnace linings, protective coatings for metal parts, and many other applications.

The other avenue of development is concerned with materials for applications in which it is necessary

to have the toughness and ductility which have been associated exclusively with metals. The term "have been" is used because recently considerable effort has been devoted to developing at least some ductility and toughness in nonmetallic materials for high-temperature use.

While there has been much talk of ductility and speculation as to the minimum ductility materials must have for structural applications, perhaps 'toughness' is the property that should be emphasized. Without being too exact, ductility is the amount of deformation a material will undergo before fracturing, while toughness is measured by the amount of energy a material absorbs prior to fracturing.

For many applications involving high-temperature service, it is necessary that a material have toughness not only at the service temperature, but also at room temperature. Components must be able to withstand handling at room temperature, as well as assembly stresses, either deliberate (tightening of bolts, etc.) or accidental (for example, from forcing slightly misaligned parts into alignment). Also, in some cases, such as turbine blades, parts may be loaded in service before they are heated to equilibrium service temperature.

The state of the art in high-temperature metals today may be summarized in one statement: *we have no tough metallic material that is fully satisfactory for service in oxidizing atmospheres* (and by far the majority of potential applications involve use in air) *at much above 1650 F.* And that is the present upper limit for the nickel and cobalt base superalloys which were developed primarily for jet engines.

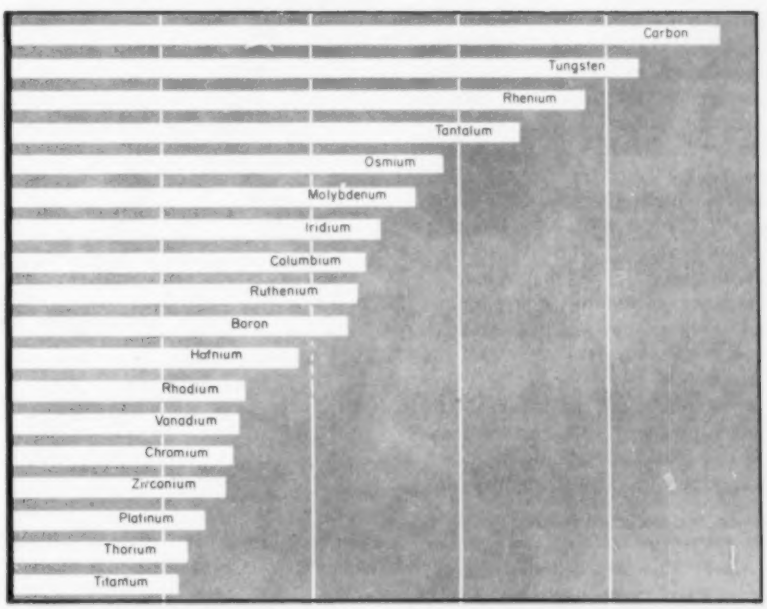
Metallurgists believe the ultimate upper limit for these alloys is probably around 1800 F. The purpose of this review is to survey the prospects for tough materials for service at temperatures higher than this.

Future temperature range

Dr. Clarence H. Lorig, technical director at Battelle Memorial Institute, has prepared the following table of probable future temperature ranges of materials for service at high temperatures:

MATERIAL	TEMPERATURE, F	REMARKS
Tungsten-base and tantalum-base alloys	2700-3500	
Molybdenum-base alloys	2200-3000	
Columbium-base alloys	2000-2500	
Chromium-base alloys	To 2400	Limited to very low stresses above 2000 F
Complex alloys containing two or more of the above metals as a base	To 3000+	
Nickel-base and cobalt-base alloys	To 1850	
Iron-base alloys	To 1700	
Iron-aluminum-base alloys	To 1400	
Titanium-base alloys	To 1200	To 1400 F for times up to 10 minutes or less
Beryllium-base alloys	To 1200	For special applications where light weight and high elastic modulus are important

It appears logical, in seeking alloys for service at the highest possible temperature, to search among the metallic elements with high melting points. Pure metals usually weaken seriously at about half the absolute melting point (melting point on the absolute temperature scale, degrees F plus 459°) and usually can be pushed to about 65% of the absolute melting point, or in some cases a little more, by alloying. Thus, we might expect that alloys for service above 1800 F should be based on metals with melting points above 3000 F. The graph below shows the stable elements which have melting points above 3000 F.



MELTING POINTS *of all stable elements melting above 3000 F.*

Glancing down the list, we can eliminate carbon, the highest melting element of all, because in light of present knowledge, it is unlikely to be capable of "toughness." It once was thought that titanium and zirconium would be suitable for high-temperature alloys because of their relatively high melting points as compared with those of iron, nickel, and cobalt. But titanium and zirconium have

proved disappointing in this respect, although they are tremendously useful in other ways. It now is believed generally that the elevated-temperature strength of a metal somehow is related to density as well as melting point, and that very high-temperature capabilities are just not inherent in these lighter metals.

Thorium has been found by experience to be weak at elevated temperature.

Hafnium is used for control rods for nuclear reactors, but so far no other commercial uses have been developed for hafnium.

Boron may be considered a sort of semimetal which does not possess toughness, although there are some metallurgists who feel the development of metallic properties in boron base materials is not hopeless. We cannot now consider it a potential structural material, although its very low density, high melting point, and thermal properties make it of possible interest for certain nonstructural applications. If it is ever developed to the point where it can be used for structural purposes, its high modulus of elasticity will be of interest.

If the elements mentioned above are eliminated from the list in the graph, and the metals of the platinum group that melt over 3000 F (osmium, iridium, ruthenium, rhodium, and platinum) are grouped together, we have the following elements which may be suitable as base metals for ultra-high-temperature alloys:

- Important refractory metals — tungsten, tantalum, molybdenum, and columbium (called niobium in Europe and less often in the U.S.).
- Metals which are scarce, little known, or faced with serious technical problems — rhenium, platinum group metals, and chromium.

Some 'scarce' metals are common

All of the metals listed, except possibly chromium, have been thought of in the past as being scarce. Actually, the earth's crust contains larger amounts of some of these metals than of some "common" metals. Figures of relative abundance in the earth's crust may be misleading with respect to practical availability, since some elements are widely distributed in extreme dilute form, but such statistics at least provide a starting point for comparison.

The table below shows the relative abundance of various metals in the earth's crusts. Several common metals are included for comparison.

METAL	ESTIMATED FRACTION OF EARTH'S CRUST *(parts per million)*	ESTIMATED WORLD RESERVES *(tons of contained metal)*
Iron	50,000	—
Chromium	200	9,000,000
Columbium	70-100	3,150,000*
Copper	70	—
Tungsten	69	1,400,000
Lead	16	—
Molybdenum	15	Over 1,500,000*
Tantalum	2.1	100,000
Mercury	0.5	—
Platinum	0.005	—
Gold	0.005	—
Rhenium	0.001	—

Note: Platinum-group metals other than platinum are about as scarce as rhenium.
*Does not include reserves in communistic countries.

Note that columbium and tungsten are about as abundant as copper (though more dilute), and molybdenum is about as abundant as lead.

The fact that additional ore deposits usually turn up when a concentrated search is made is well illustrated by the case of columbium. Present estimates of reserves are more than three times what they were five years ago, based on enormous deposits found recently in Africa and Canada as a result of an intensive search for several metals of interest to the atomic-energy program. Because of scarcity, rhenium and the platinum-group metals can be considered only for very special applications.

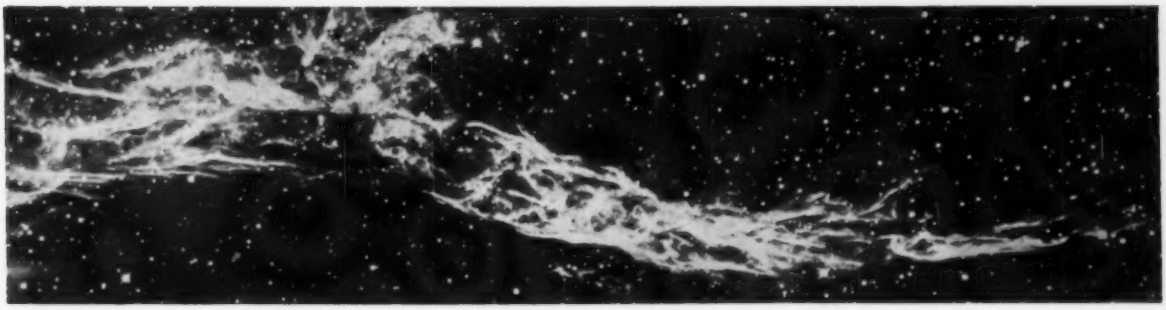
Chromium, molybdenum, tungsten, and to a lesser extent columbium have been used for years as alloying elements in other metals, especially iron and steel. In addition, tungsten and molybdenum have been used in the lamp and electron-tube industry for more than 40 years. It is only since World War II, however, that these metals have been seriously considered for use as structural metals in their own right, and even today, only a small fraction of their total production is for structural uses. Commercially puré tantalum has been used for many years, in modest quantities, as a structural metal in the chemical industry and elsewhere for its corrosion resistance.

Columbium now appears to be more plentiful than tungsten or molybdenum. But since it was thought to be very scarce until a few years ago, intensive development of columbium as a base for heat-resistant alloys began comparatively recently. Thus production is still comparatively small. On the other hand, a large proportion of the world's reserves of molybdenum are concentrated in one large deposit which has been known for a long time (Climax Molybdenum Company's property in Colorado), and additional molybdenum is produced as a by-product of copper mining.

Until recently domestic availability of tungsten was considered very limited. Although domestic tungsten deposits have been found capable of meeting immediate needs, the largest deposits are in China (77% of known world reserves).

Because of the above considerations and because of a desirable combination of properties, of all the refractory metals molybdenum has received by far the greatest attention as a structural metal.

Chromium is produced in large quantities for plating and use as an alloying element in other metals, but at present it is not being used as a metal in its own right because of metallurgical difficulties. With-



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in the past two or three years, rhenium has come into use in extremely small quantities.

Our interest, then, focuses on about a half dozen metals which now seem most likely to succeed as structural metals in the super-hot applications of coming years.

Tungsten: 'hottest' metal

Tungsten has the second highest melting point of any element (only carbon is higher) and the highest of any metal. Tungsten is one of the most dense metals; its density is exceeded only by that of rhenium, gold, and some of the platinum-group metals. Tungsten metal of commercial purity is very hard, brittle, and difficult to form and machine.

Tungsten occurs primarily in complex oxides with iron and manganese or calcium. Purified oxide is prepared from these minerals and reduced with hydrogen to form tungsten powder. Normally this is consolidated by pressing and sintering, although experiments now are underway in arc melting and electron-beam melting. Practically all the metallic tungsten being made in the form of sheet, rod, and wire currently is going into electrical contacts, lamp filaments, and electron-tube components. But a need for much larger tungsten components in certain advanced aircraft and missiles is anticipated.

The price of heat resistance

U. S. consumption and prices of some of the metals under consideration may be tabulated like this:

METAL	EST. CURRENT U. S. CONSUMPTION[a] *(pounds unless otherwise specified)*	PRICE *(dollars per pound unless otherwise specified)*
Tungsten	8,100,000 (includes over 1,000,000 lb. tungsten metal)	$12-$100 (large price range reflects difficulty of working to thin sheet)
Molybdenum	30,000,000 (includes about 1,000,000 lb. molybdenum metal)	$12 – $35
Tantalum	500,000	$60 – $100
Columbium	1,400,000	Over $50
Platinum group	675,000 troy oz. (1952)	$90 – $160 per troy oz.
Rhenium	100 (est.)	$700 (approx. price for powder)
Chromium	400,000 tons[b] (none used as structural metal)	$1.20 – $4.65 (depends on grade – price is for commercially "pure." No price is available on "ductile" chromium)

NOTE: Prices listed for the first four metals are spread of mill product prices (rod, sheet, wire, etc.). Other prices are for metal as recovered.

(a) All uses including alloying with other metals, etc.

(b) Estimated amount of contained metal in all chrome ore consumed in U. S., including that used as source of chromium for electroplating and that used in refractories.

A MOLYBDENUM WIRE *(left), heated well above 2000 F, oxidizes visually. At right, a similar moly wire is protected with a molybdenum disilicide coating developed at Battelle.*

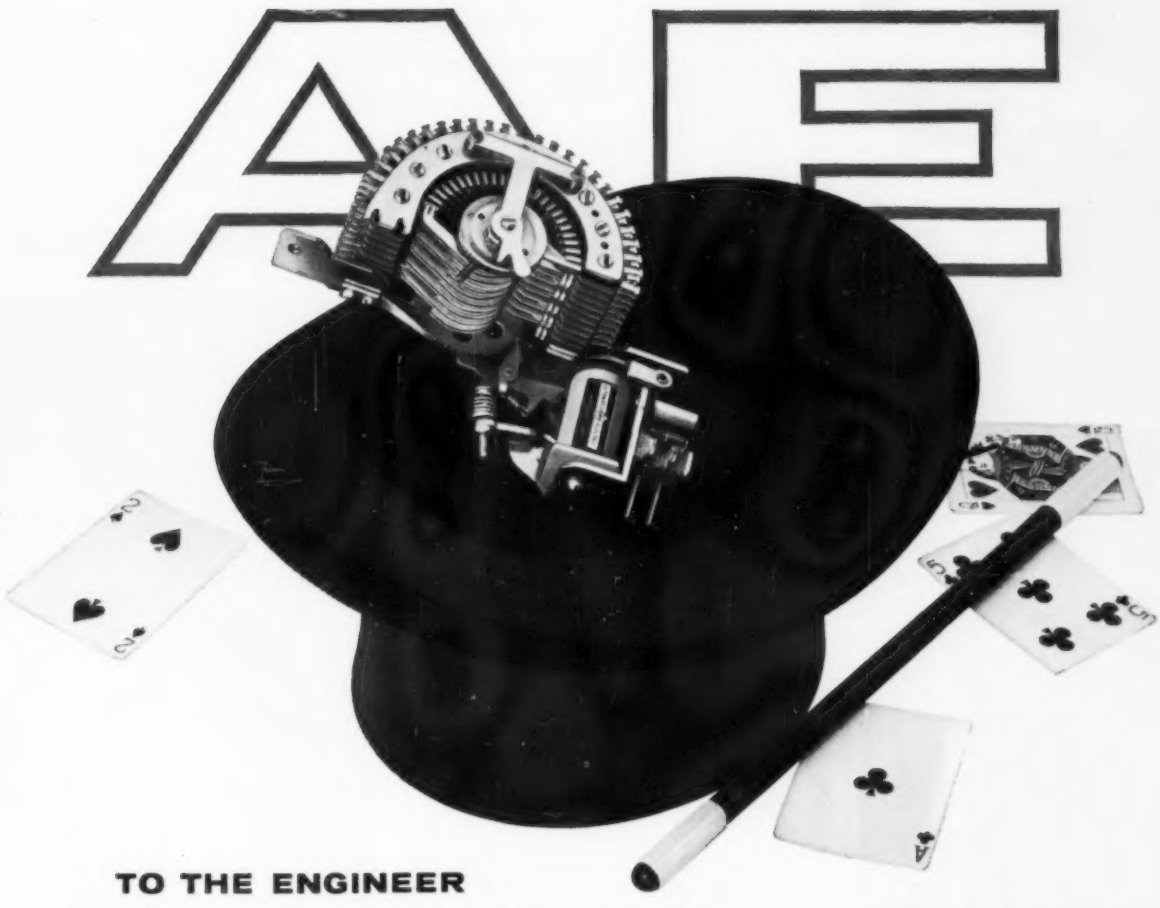
No tungsten alloys have reached the commercial stage, but development work is underway to improve both high-temperature strength and room-temperature ductility by alloying. The protection of tungsten against oxidation has not been studied extensively yet, but protection will be necessary. The protection of molybdenum has been studied more extensively, and it is likely that much of the work on protecting molybdenum will be applicable to tungsten.

Available molybdenum

Although there are four metals with higher melting points than molybdenum, it is far more available than any of them (although tungsten is more plentiful in the earth's crust). The density of molybdenum is about 30% higher than steel but only a little over half that of tungsten. It is much less hard and brittle than tungsten, but ductility is strongly influenced by small amounts of oxygen, carbon, and nitrogen; commercial metal tends to have what metallurgists term "grain-boundary weakness," which can lead to brittle behavior under some conditions. For structural applications, molybdenum technology is considerably further advanced than tungsten technology.

Molybdenum occurs primarily as the sulfide which is roasted to oxide, purified, and reduced to molybdenum powder with hydrogen. The molybdenum powder is consolidated into solid metal either by pressing and sintering (in hydrogen or vacuum), or arc melting in vacuum by the consumable-electrode cold-mold process to produce what is known as arc-cast molybdenum. Thus there are two types of molybdenum. ■

IN THE NEXT ISSUE *Part II of "The World's Hottest Alloys" will discuss working, welding, and coating molybdenum; tantalum; columbium; rhenium; chromium; the platinum group; and other metal-ceramic composites. Part II will conclude the article.*



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Tomor

I-R illustration by Felix Palm

EVER SINCE Georges Destriau back in 1936 discovered what has now become the useful type of electroluminescence, and especially since Westinghouse lighted an experimental room with it 20 years later, the thin, flat panels of "EL" have been hailed as "tomorrow's light."

Now—with Westinghouse's commercial introduction of EL nightlights, lighting panels up to two feet square, industrial control panels, and variable-color display systems—tomorrow's light is rapidly becoming today's light.

To complete the promise of a revolution in lighting, and now on the threshold of practical application, are flat "picture-frame" TV screens, EL fluoroscopes of unprecedented magnification and brightness, and drapes and other flexible fabric-lights. Also being effected in several industrial laboratories are "thermoelectric-electroluminescent" cells which will make it possible to cool, heat, *and* light your office or home with combination wall panels.

How it works

What is electroluminescence? What makes it work?

Stated simply, EL is the generation of light in a solid (or liquid) material by the application of a voltage, in such a way that the light emission does not result from heating.

Thus, electroluminescence is "cold light," in common with other forms of luminescence, including the firefly's torch, cathode-ray tubes in TV sets, and fluorescent lamps.

The emission process is essentially the same in all forms of luminescence; what differs is the means of excitation, the way in which energy is supplied to the phosphor. In electroluminescence the energy is obtained by the acceleration of electrons, *not in a vacuum, but inside the solid itself.*

Electroluminescent phosphors (electroluminors) are the offspring of a marriage between luminescence and semiconductor physics. As might be expected they are more complex than ordinary phosphors for excitation by external sources such as cathode rays, x-rays, or ultraviolet radiation, and hence are rarer and often more temperamental.

One form of electroluminescence (now called "recombination electroluminescence") was discovered as long ago as 1923 by Lossew in Russia. Although still studied experimentally,

1. EL inspection reveals imperfections with a uniform, glareless light.

2. Area sources of light now supplement point sources (incandescent) and line sources (fluorescent).

3. Retouching of films is an immediate use for EL's cold light.

4. Thermoelectric-luminescent panels that would combine lighting with heating (or cooling) are being explored.

by **Dr. Henry F. Ivey,** *manager of phosphor research, Westinghouse Lamp Division*

row's light is here

AN ELECTROLUMINESCENT-USING FACTORY *could be built today taking advantage of EL's fail-safe and thin-lamp control panel advantages (left); glareless parts inspection (left center); transparent light-and-skylight (top); drawing board uniformity (center); see-through walls of light (right); and flexible electroluminescence as drapes (far right). Today's uses are limited to low-light devices such as shown above. But medium-light level applications are expected to create a $6- to $8-million electroluminescent market as early as next year.*

its efficiency is too low for commercial application.

Today's EL products derive from the "Destriau effect," or "high-field electroluminescence." It differs from the first type in requiring very high electric field strengths, of the order of 100,000 volts per centimeter. In practice, these are obtained by applying a few hundred volts between electrodes spaced only a few thousandths of an inch apart. Between these electrodes, like the meat in a sandwich, is the electroluminescent phosphor.

Thus an EL lamp or cell is basically an electrical capacitor, the dielectric being specially selected so that it will emit light when a voltage is applied. Obviously at least one electrode must be transparent to utilize the light generated.

Most electroluminescent phosphors currently used consist of zinc sulfide to which small and carefully controlled amounts of an activator and a coactivator have been added. The activator is responsible for the luminescent emission and is usually copper or manganese. The co-activator may be one of the halogens or a trivalent element such as aluminum. As is true of all phosphors, undesired elements must be kept scrupulously below a few parts per million.

Commercially usable electroluminescent phosphors are available only in powder form. For experimental work the phosphor may be suspended in an insulating liquid, but for most practical applications a solid dielectric obviously is preferred.

In the "glass-plastic" type of lamp, the phosphor is embedded in a plastic material and applied to the surface of a piece of glass previously coated with a thin, transparent, electrically conductive film of tin oxide. The second electrode may consist of either aluminum deposited in a vacuum or silver paint. Generally, the back of the lamp also is coated with plastic for electrical insulation and as a protection against moisture.

Unbreakable, flexible lamps

A variation of this type of construction—replacing the glass base with a plastic sheet—produces an unbreakable lamp. In this case some other type of transparent electrode must be used because the temperature at which tin oxide coatings are prepared precludes their application to plastic materials.

(Results of an Industrial Research survey)

THE ELECTROLUMINESCENT MARKET

An EL plug-in nightlight, above, is now being marketed by Westinghouse. Larger panels in assorted sizes (top) are ready for sale, but these require higher-than-home-use voltages.

THIS YEAR'S MARKET: Low light devices—the 1 to 5-foot-lambert level where illumination is effective only to the dark-adapted eyes. One mass market being tapped this year by Westinghouse with its 2¼ X 2¼ plug-in Rayescent lamp is the $3.2 million night light business. Outlets are Sears, Woolworth, and similar stores. Some 1960 autos will have Sylvania EL clock dials, probably Chrysler cars. Other devices being made on a limited basis are readout lamps, factory panels for shadow-inspection of parts, aircraft cockpit and control lights, directional signals for photographic processing laboratories, and advertising displays.

NEXT YEAR'S MARKET: Utility products at medium level—5 to 20-foot-lamberts. These will be engravers' striping tables, drafting tables, flat x-ray readers, decorative table tops, photographic darkroom safe lights, and talley boards. Estimated size of the EL market during 1960 is in the neighborhood of $6 to $8-million.

IN TWO TO FIVE YEARS: Electronics marketing men are talking about "several" years hence for applications in this order—imaging devices ("windshield radar," flat TV, fluoroscopes), computer and control elements, solid-state relays and switching devices, "light-up" fabrics, rollable shades of light, home accent lighting, general office lighting, and glareless drafting room and factory illumination.

PROSPECTS FOR MASS-MARKETING ILLUMINATION: General lighting in the form of wall and ceiling panels operable on standard 60-cycle house current must wait for a major breakthrough. If this breakthrough has been made, or is imminent, it is being kept secret. Most electronics officials are confident the breakthrough is inevitable and that EL promises a "tremendous market" in the next decade. Possibly five to seven years hence EL is expected to become a competitive light source with no less than a $35 to $50 million share of the lighting market.

PRINCIPAL PATENT HOLDERS: Westinghouse, Sylvania, General Electric, and Radio Corporation. About 75 to 100 basic patents and applications are held or filed in devices, materials, and processes by these firms. Major companies are believed to be negotiating with each other for licensing rights.

If the plastic base in this all-plastic type of lamp is made thin enough, it is possible to construct a flexible lamp which can be rolled up on a common window shade roller. Metal mesh or cloth of electrically conducting fibers also may be utilized for an endless variety of flexible electroluminescent lamps.

Further diversification can be achieved by embedding the phosphor in an inorganic enamel or glass of low melting point, rather than in an organic plastic material. The support in this case may be metal, leading to the "metal-ceramic" type lamp that looks like ordinary porcelain enamelware. Such an EL cell could become a bathtub, sink, or swimming pool of light. The base also may consist of glass.

Experimental electroluminescent lamps using continuous transparent phosphor films rather than powders embedded in a dielectric also have been made, thus making transparent lamps possible.

The first application of electroluminescence to be marketed as a consumer product is the "Rayescent" lamp safety light. This is a small, flat 2¼ x 2¾-inch rectangle that plugs directly into a standard electrical wall outlet. Unlike the 7½-watt incandescent night light which it replaces, the EL lamp lies flat against the wall, out of the way. Power consumption is only 1/200 watt. If left on 24 hours a day, the cost (at three cents per kilowatt-hour) would be a tenth of a cent per year. The life of such lamps is expected to be at least 10,000 hours, or more than a year of continuous burning.

Immediate applications

So far only electroluminescent lamps with uniform illumination over the area of the lamp have been discussed. Many other interesting and useful applications become possible if one of the electrodes is subdivided into a geometrical pattern. Indicators for the flow of traffic in railroad yards or for the control of chemical processing plants are made easily in this way. Animated advertising or warning signs also are feasible. Any of these devices may utilize several phosphors or different emission colors.

The second EL application to be marketed widely is that of "read-out" lamps utilizing subdivided electrodes to present numerical or alphabetical information. In one model, a seven-segment design permits formation of

***USING LIGHT** in places such as this is done either with electroluminescent panels or not at all, since drawer above prevents use of bulky conventional fixtures.*

the numerals 0 through 9. A 10-segment design, however, gives better legibility, and allows formation of 16 letters and many symbols, including positive and negative signs. A 14-element design permits display of all letters of the alphabet, numerals, and additional symbols.

Such display lamps should find application in digital voltmeters, computer read-out devices, stock quotation boards, athletic score boards, train or airplane indicators—anywhere that changing numerical or alphabetical information must be displayed.

For such uses EL has many advantages over incandescent or glow-discharge lamps and electromechanical methods now being used. These include high reliability, small space due to thinness of the lamp, good legibility, wide-angle viewing, lack of parallax, long life, negligible heat generation, and low power consumption (about 0.1 watt per letter or numeral).

They never burn out

EL lamps also include a fail-safe feature, since they do not burn out, but rather decrease in light output during life. This is an important advantage in some data-handling applications where lamp failure might go undetected and cause an erroneous indication.

Present commercial lamps of the glass-plastic type have about 50% of their initial output remaining after 1,000 hours of operation under normal conditions, 120 volts, 60 cycles per second, and room temperature. For longer periods of operation the deterioration is very slow and the lamp will burn for many thousands of additional hours. The maintenance of output for ceramic-embedded phosphors is generally better than those embedded in plastic, but the initial brightness is lower.

High-performance EL phosphors emitting in the blue, green, or yellow regions of the spectrum are available. These phosphors can be blended to give white-emitting lamps. Currently, a commercially satisfactory red emitter is lacking, but promising developments are underway in the laboratory.

Special phosphors can be prepared that change their emission color as the operating frequency is varied—for example, from yellow to green to blue for successively higher frequencies. Blends also may be used to accentuate color shifts. Multilayer multicolor lamps also can be constructed, any single layer or combination of layers being energized by a suitable switch.

Since electroluminescent lamps are essentially capacitors, they can be tuned to different frequencies by means of external inductances. In this way, the color of a multilayer lamp can be varied by changing the frequency of the applied voltage. This is what you may do, soon, when you "dial your walls to a warmer color."

Perhaps the most striking feature of electroluminescent lamps is their shape. Incandescent lamps are essentially point sources of light; fluorescent lamps are line sources; but electroluminescent lamps are true area sources of very small thickness. Consequently they can be produced in any size or shape and with holes or openings, their thickness depending upon that of the supporting base.

EL saves construction dollars

The thickness of such light sources is an important potential factor in the lighting of newly constructed skyscrapers. Fluorescent lighting fixtures, for example, may require one-half to one foot of space. At typical construction costs of one to two dollars per vertical foot per square foot of floor area, an electroluminescent installation, even including a special high-frequency power supply, could result in savings of millions of dollars.

The goal of lighting equipment manufacturers is the widespread use of electroluminescence to supplement conventional light sources in homes, offices, factories, and public buildings. The architectural advantages of EL stagger the imagination. Panels of light, circles of light, whole walls, floors, and ceilings of light are more than novelties. For the first time, lighting can become a truly integral part of the design of most objects.

Imagine, for instance, a wall separating two rooms capable of illuminating both of them simultaneously with uniform, glareless light of variable intensity and color. Or light also can be used in the construction of domes, doors, stairs, draperies, or furniture.

Before this can happen on a widespread scale, however, the efficiency must be increased further. The ultimate goal is to attain the necessary brightness levels at ordinary 60 cycles per second (cps) line frequency. For present, higher-frequency operations, special frequency converters using power transistors and "square loop" magnetic materials already have been designed and constructed. These are about the same size as the ballasts used with fluorescent lamps.

THE AUTHOR

One of America's leading electroluminescence scientists, Dr. Henry F. Ivey has been experimenting with EL-associated phenomena since his days at MIT, where he received his Ph.D. in physics in 1944. Ivey, now manager of phosophor research at the Westinghouse Lamp Division, held teaching and research positions at the University of Georgia, MIT, and National Union Radio Corp. before joining Westinghouse in 1946.

EL brightnesses at high-frequency operation are now adequate for room illumination, but cost is prohibitive.

The cost of brightness

The brightnesses achieved with high-frequency operation are quite adequate for purposes of illumination and experimental rooms have been lighted in this way. Unfortunately, the cost of operation is now prohibitive for widespread use.

The brightness of electroluminescence increases with the magnitude or the frequency of the applied voltage. The maximum voltage—hence the attainable brightness for a given frequency—is limited by dielectric breakdown. Operating voltages thus are determined by the thickness of the phosphor-containing layer; lamps now on the market are being made to operate at 120, 240, 350, 460, and 600 volts.

At frequencies of several thousand cycles per second or lower, doubling the frequency produces an increase of 60 to 80% in output. At higher frequencies, however, there is less increase in output from increased frequency. Part of this limitation at high frequencies arises from the phosphor itself, but the resistance of the electrodes also may become a factor.

In the laboratory, brightness of 2500 foot-lamberts have been obtained in EL cells operating at 600 volts and 20,000 cps. This is somewhat brighter than a 40-watt fluorescent lamp (about 1700 foot-lamberts). A commercial green-emitting EL lamp operating on ordinary line voltage (120 volts and 60 cps), however, emits only about 1.4 foot-lamberts. (One foot-lambert represents one lumen of light radiated per square foot of surface; a standard candle emits 12.5 lumens.)

Maximum brightness and maximum efficiency, unfortunately, are not achieved under the same conditions. Unlike the case for brightness, there exists an optimum voltage for maximum efficiency. This optimum voltage is usually about half the maximum operating voltage of the lamp, and the output at this point is considerably below that obtainable at full voltage. Furthermore, efficiency is better at frequencies of a few hundred cycles per second than at higher or lower frequencies.

14 lumens per watt

In the laboratory, efficiencies as high as 14 lumens per watt have been obtained under optimum conditions for lamps with green emission. The values for commercial lamps at normal operating conditions are only about 3 lumens per watt.

By comparison, the efficiency of a standard 100-watt tungsten filament lamp in a bare socket is 16 lumens per watt, but a diffusing fixture may reduce this to only 5 or 6. The efficiency of a bare fluorescent lamp is about 65 lumens per watt; in a diffusing fixture this is reduced to about half. Light from an electroluminescent lamp is already diffuse, of course, and no losses are encountered in additional diffusing fixtures.

Despite EL's present drawbacks for economical general lighting, there are many other specialized applications permitting lower brightness levels and less efficiency where an area source of light is ideally suited. Among such uses are illuminated electric switch plates, radio and electric appliance dials, clock faces, warning and advertising signs, elevator signals, stair markers, and many others.

The lighting of control panels in aircraft and automobiles and all kinds of instruments can be done most effectively with electroluminescent lamps. Because of the uniformity of its light, EL also is ideal for illuminating maps, drawings, or other transparencies.

'Picture-frame' TV

One of the most revolutionary applications of electroluminescence is in imaging devices. Today all television and radar displays are based upon the cathode-ray tube. Such tubes have many advantages, including high resolution and ease of signal distribution (scanning) and modulation (variations in light intensity).

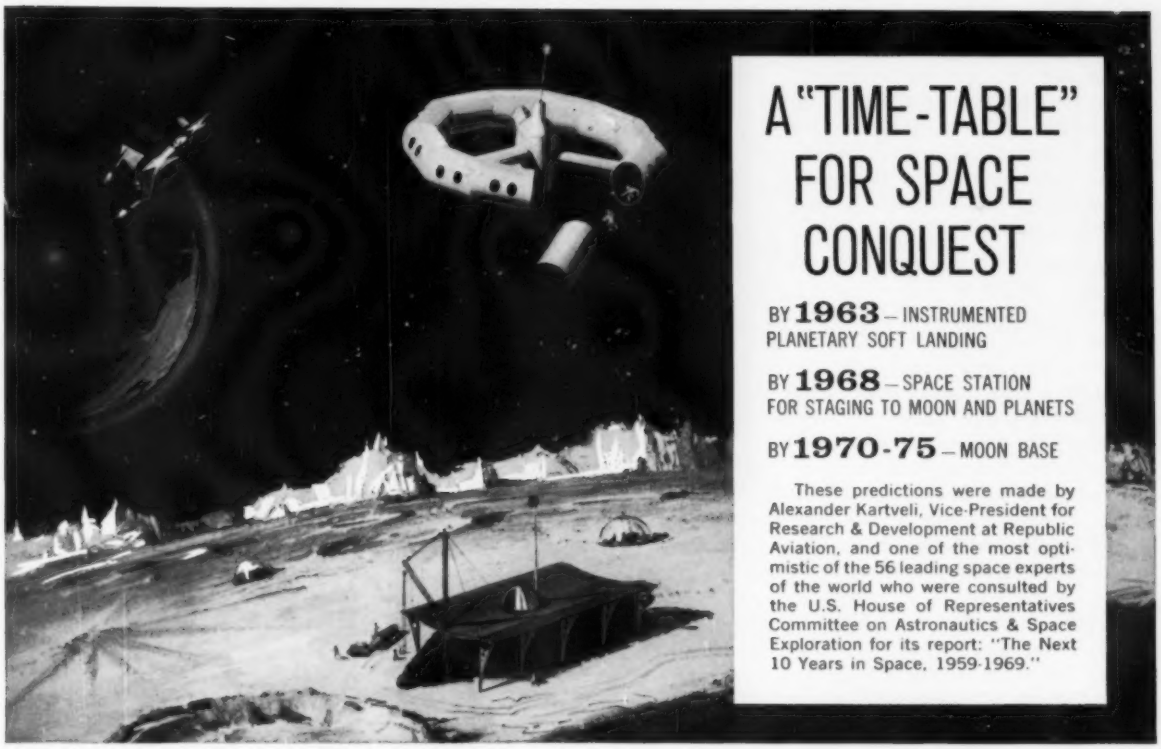
Their major disadvantages are size and weight. Although the beam deflection angle has been increased progressively, the depth of such tubes is still appreciable. Also, the weight of the glass or metal bulb for large screen size is considerable because of the wall thickness required to contain the vacuum under atmospheric pressure.

Windshield radar

Electroluminescence, on the other hand, permits a thin two-dimensional display of almost unlimited size, with no vacuum. With further development of phosphor films, these devices also will be made transparent. It has been suggested, for example, that such displays could be incorporated into the windshields of aircraft, making it possible to present radar and other information to the pilot without obstructing his vision.

In principle, solid-state image display devices are very simple. It is only necessary to place on each side of a layer of electroluminescent material a set of electrodes in the form of parallel conducting strips, the strips of one set being perpendicular to

FLEXIBILITY *is an intriguing possibility inherent in electroluminescence, since EL cells can be made of pliable plastic.*



A "TIME-TABLE" FOR SPACE CONQUEST

BY **1963** – INSTRUMENTED PLANETARY SOFT LANDING

BY **1968** – SPACE STATION FOR STAGING TO MOON AND PLANETS

BY **1970-75** – MOON BASE

These predictions were made by Alexander Kartveli, Vice-President for Research & Development at Republic Aviation, and one of the most optimistic of the 56 leading space experts of the world who were consulted by the U.S. House of Representatives Committee on Astronautics & Space Exploration for its report: "The Next 10 Years in Space, 1959-1969."

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It's the fervent conviction of engineers and scientists at Republic Aviation that the courageous "Space Time-Table" above is entirely feasible – given a tradition-free, integrated approach to the problems. Such an approach is evident at Republic Aviation. Here, groups of specialists from many disciplines are working in close collaboration to solve problems across the entire spectrum of space technologies, which limit today's interplanetary and upper atmosphere flight capabilities.

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Airborne Navigational Systems
Jamming & Anti-Jamming
Miniaturization — Transistorization
Ranging Systems
Propagation Studies
Ground Support Equipment

Thermo, Aerodynamics
Theoretical Gasdynamics
Hyper-Velocity Studies
Astronautics Precision Trajectories
Airplane/Missile Performance
Air Load and Aeroelasticity
Stability and Controls
Flutter & Vibration
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Hydromagnetics
Ground Support Equipment

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Combustion and Detonation
Instrumentation
High Power Pulse Electronics

Nuclear Propulsion and Radiation Phenomena
Nuclear Weapons Effects
Radiation Environment in Space
Nuclear Power & Propulsion Applications
Nuclear Radiation Laboratories

Send resume in complete confidence to: Mr. George R. Hickman, Engineering Employment Manager, Dept. 25G

REPUBLIC AVIATION
Farmingdale, Long Island, New York

For additional information, circle No. 8 on the Readers Service Card, page 101.

those of the other set. If a voltage is connected between the two electrodes, one in each set, light will be emitted at the intersection of the two strips. The voltage applied controls the intensity of the light. By suitable switching and variation of the voltage, a picture or any other desired pattern may be reproduced.

Many problems must be solved before such solid-state image displays are commercially feasible. One is the distribution of signals to the many thousands of picture elements required for a high-resolution display in the brief time allowed in normal radar and television systems. Because time and resolution requirements of radar are not as severe as those in television, and economic factors are less important, radar probably will see the first successful application of such devices.

Another problem is that not only will the point lying at the junction of the two selected electrodes be illuminated, but also all other points lying along the two electrodes. This "crosstalk" obviously will degrade the quality of the image. Although it can be eliminated, the systems to do this become rather involved. The use of specially prepared phosphors, however, can help alleviate the problem.

Finally, since only one element is energized at a time (and in a practical display there must be many elements), the average light output in the simple system described would be quite low.

Intensive work is underway in many laboratories to solve these and other problems. The goal is production of practical large-area, thin, solid-state display devices — for "picture-frame" TV, giant radar screens, and other uses. Meanwhile, research is going on to develop electroluminescent storage cells for computers.

'Opto-electronics'

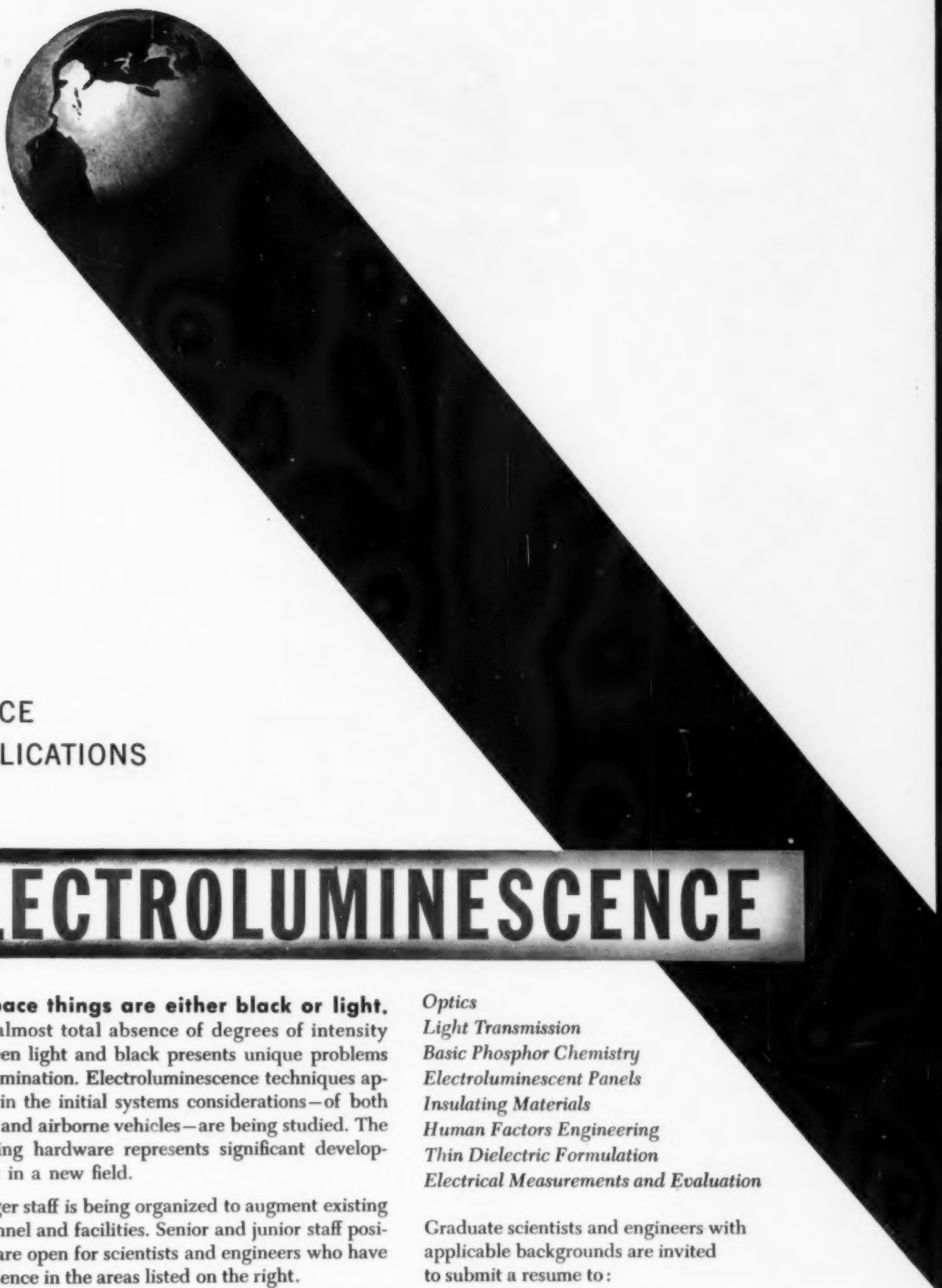
From an electronics viewpoint, an electroluminescent cell is a transducer with electrical input and optical output, while a photoconductor is a transducer with optical input and electrical output. Combining these inverse functions results in a variety of useful circuit elements for which the name "opto-electronics" has been suggested.

One simple combination provides a solid-state relay, or switch, with no moving parts and with complete electrical isolation of input from output, since the connecting link is optical.

(continued on page 88)

I-R illustration by Gus Methe

BOTH ARE 20-STORY BUILDINGS *with the same amount of usable space in each. More economical, shorter buildings, such as the one at right, could result from widespread use of electroluminescent lighting by eliminating a half to one foot of vertical space required for fluorescent fixtures.*



SPACE
APPLICATIONS
OF

ELECTROLUMINESCENCE

In space things are either black or light. This almost total absence of degrees of intensity between light and black presents unique problems in illumination. Electroluminescence techniques applied in the initial systems considerations—of both space and airborne vehicles—are being studied. The resulting hardware represents significant developments in a new field.

A larger staff is being organized to augment existing personnel and facilities. Senior and junior staff positions are open for scientists and engineers who have experience in the areas listed on the right.

Optics
Light Transmission
Basic Phosphor Chemistry
Electroluminescent Panels
Insulating Materials
Human Factors Engineering
Thin Dielectric Formulation
Electrical Measurements and Evaluation

Graduate scientists and engineers with applicable backgrounds are invited to submit a resume to:

Mr. R. A. Martin, Supervisor
Professional Placement Staff
HUGHES RESEARCH AND DEVELOPMENT LABORATORIES
Culver City 59, California

HUGHES

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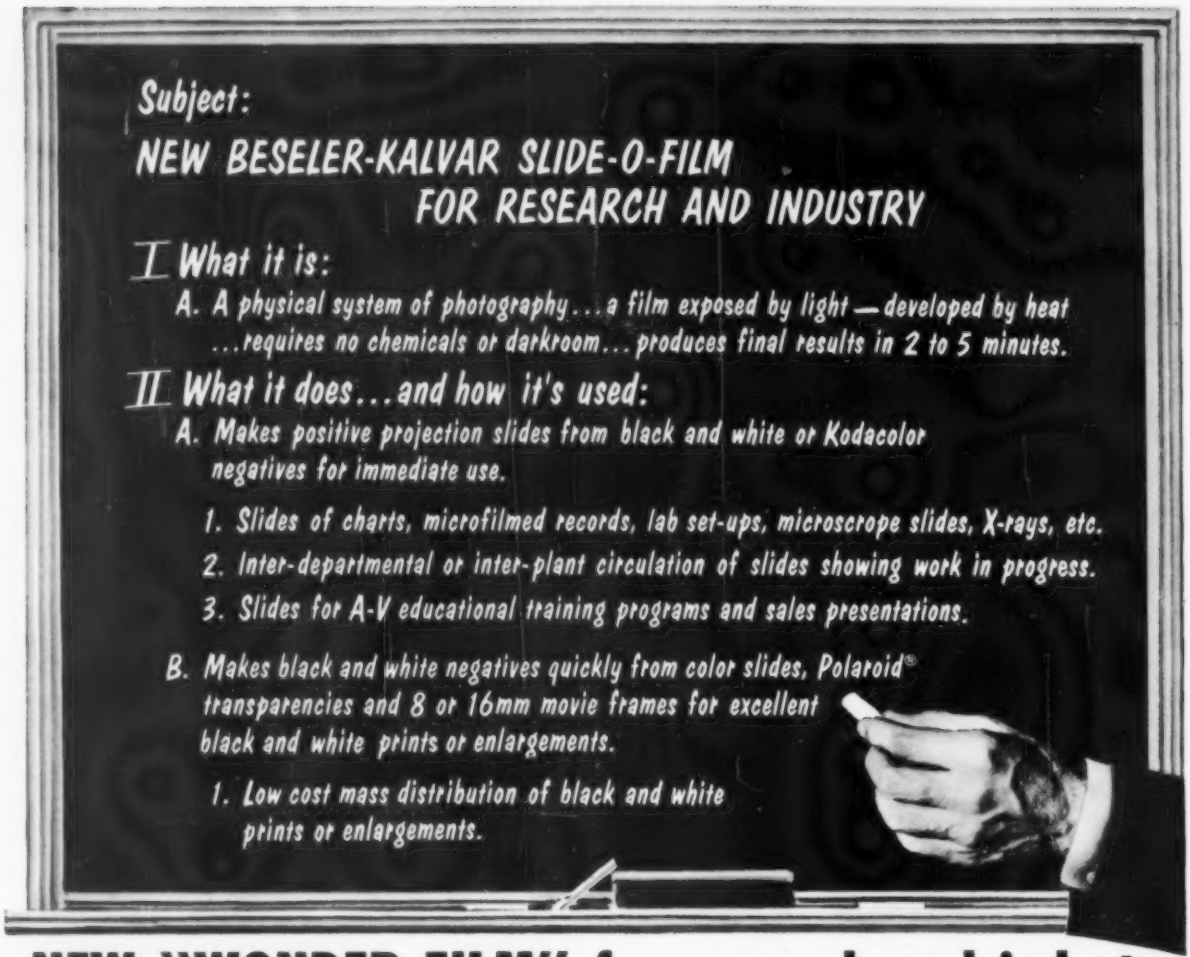
For additional information, circle No. 9 on the Readers Service Card, page 101.


Subject:
NEW BESELER-KALVAR SLIDE-O-FILM
FOR RESEARCH AND INDUSTRY
I What it is:
A. A physical system of photography... a film exposed by light — developed by heat ...requires no chemicals or darkroom... produces final results in 2 to 5 minutes.
II What it does... and how it's used:
A. Makes positive projection slides from black and white or Kodacolor negatives for immediate use.
1. Slides of charts, microfilmed records, lab set-ups, microscrope slides, X-rays, etc.
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B. Makes black and white negatives quickly from color slides, Polaroid® transparencies and 8 or 16mm movie frames for excellent black and white prints or enlargements.
1. Low cost mass distribution of black and white prints or enlargements.

NEW "WONDER FILM" for research and industry ...makes projection positives from negatives... negatives from color slides, in minutes... without darkroom or chemicals

Beseler Slide-O-Film . . . exposed by light and developed by heat, is a revolutionary new photographic tool for high-speed production of positive transparencies from negatives and negatives from color transparencies without the use of chemicals or darkroom . . . at ½ your present costs. New Slide-O-Film is simple to use . . . a physical system of photography — recently made available for civilian use after 10 years of development and use by government agencies — does away with darkroom and chemical procedures. Simply place the original transparency or negative, (emulsion to emulsion) against a piece of Slide-O-Film . . . expose in an ordinary projector . . . subject the exposed film to a heat source, and final development is complete.

Research and Industrial Applications . . . new uses for Slide-O-Film . . . are developed daily by research and industrial photographers. The Slide-O-Film Research and Education Department, established by the Charles Beseler Company, is ready to inform you of all developments applicable to your company's operations . . . to consult with you and examine specific applications of Slide-O-Film to your problems and projects.

For complete information address your inquiries to:

CHARLES BESELER COMPANY

237 South 18th Street East Orange, New Jersey

CB SLIDE-O-FILM DIVISION

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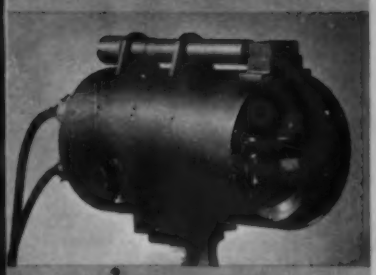
1

2



3

4

INFRARED DETECTOR *(1) utilizes photoelectromagnetic effect in the indium antimonide crystal filament (2). Signal from the instrument (3) may be fed into a meter (4) or oscilloscope.*

RESEARCH

TRENDLETTER

3rd quarter, 1959

Dear Sir:

Many of today's problems in heat-resistant metals and alloys, as well as other industrial applications involving temperature measurement and quality control, soon may be handled by infrared detection devices.

Several firms already are using infrared radiation thermometers for high-speed, precise, non-destructive testing and remote temperature measurement. Although initial cost of infrared is somewhat higher than direct contact devices, net savings in manhours is proving infrared a low cost industrial technique.

Industry may have to reappraise present control techniques in terms of infrared. Infrared designers in airborne search, early warning, track, missiles, etc. will utilize advanced detectors.

By measuring the thermal, or infrared, radiation emitted a relatively inexpensive radiation thermometer (one model's price: $2,000) can determine object temperatures without physical contact—from room temperature to 8000F. Temperatures may be measured with high sensitivity in time intervals as short as 1/100,000th of a second.

One infrared device, the Thermodot thermometer (radiometer), developed by Radiation Electronics Co, 8241 N. Kimball Av, Skokie, Ill., has a crystal sensing element of indium antimonide. This infrared sensing detector is located in the optical head of the instrument. High sensitivity, relative ease of cooling, low microphonic susceptibility, and fast response are said to make the indium antimonide detector of particular value in infrared system design.

Examples of infrared at work:

General Electric's Industrial Heating Dept checks temperature of a steel strip moving at 2,000 ft a minute through a tinplate steel annealing furnace. Method: detection of infrared rays from the strip by means of a radiation thermometer aimed into the furnace.

A western tire manufacturer pinpoints structural defects while a tire rotates at 100 mph. Former testing required location of "failure" spots by destruction and time-consuming lab analysis. Method: radiation thermometer remotely detects temperature variations which are displayed on an oscilloscope.

An aircraft manufacturer makes remote temperature readings of inaccessable structures and materials being bombarded within a nuclear reactor. Method: radiation thermometer detects and analyzes infrared emission at one-millisecond intervals.

A leading refrigerator manufacturer, as a result of laboratory tests, is now able to isolate voids and flaws in polyurethane insulation. This will mean non-destructive testing and 100% quality control at the assembly line stage —taking less than one minute for inspection. Method: infrared scanner using sensitive detector; thermal image displayed on cathode ray tube for direct viewing.

Nose cones under wind tunnel testing at very high Mach numbers . . . Rapid temperature variations were measured and recorded. Method: radiation thermometer and high-speed recorder.

◀ Thermal mapping techniques provide human skin temperature patterns showing arterial flow and activity of near-surface tumors—demonstrating the sensitivity of infrared detection devices.

THERMOGRAPH of face indicates higher temperatures in white areas. Contrast between black and white represents temperature difference of 2° C.

Determination of rubber-to-metal bonding and non-destructive testing of various laminates have been achieved by applying infrared methods. The technique utilizes the effect of bond on thermal conductivity.

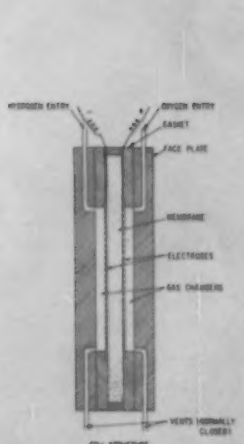
Pipe welds may be inspected continuously by infrared detection. The pipe section is passed under the coil of a high frequency generator. Near-surface weld defects, such as cracks are identified immediately by radiation thermometers.

metals

The addition of 0.1% palladium to titanium produces a corrosion-resisting alloy that resists acids. Union Carbide Metals, 30 E. 42nd St, New York 17, reports that the combination of titanium with any noble metal (rhenium, platinum, etc.) decreases the rate of acid corrosion attack to less than .01 in. per year.

Fluoride coatings can be formed on copper, aluminum, and other metal wires for high insulation at elevated temperatures—almost to the melting point of the conductor.

Developed at Bell Telephone Labs, 463 West St, New York 14, the coatings do not hinder flexibility and are non-porous. A suggested application of the wire insulation is in missile re-entry guidance systems.



electronics

◀ A fuel cell that produces electricity directly from gaseous fuel has been developed at the General Electric Research Lab in Schenectady, NY. Thermal efficiencies over 60% have been obtained.

The cell produces low-voltage direct current, with highest densities of 30 ma/cm^2, and has operated for more than 100 days in tests. It is reliable, simple, and portable—a few inches in diameter. It can be used in military and space vehicles, or in civilian applications not requiring high power.

Electrical transistors and miniaturization techniques are integrated in a hand-operated artificial larynx.

The device is a modified telephone receiver serving as a throat vibrator, a transistorized pulse generator with pitch control and a battery power supply. Modular techniques were used in miniaturization of experimental units. (Bell Telephone Labs, 463 West St, New York 14)

nuclear

A tiny cobalt-60 isotope capsule replaces 2- to 3-million volts to power Cyclops—the highest-capacity radioisotope machine ever used industrially.

In photograph Cyclops' gamma rays radiograph heavy steel castings to insure freedom from defects in the metal. Cyclops was developed by Picker X-Ray Corp, 25 S. Broadway, New York.

A nuclear-fueled, turboelectric powerplant has been designed to provide auxiliary power for large interplanetary manned space vehicles. The craft probably would be built in space for use strictly between space stations in orbit around planets—never landing.

The spacecraft design, created at NASA's Lewis Research Center, Cleveland, uses sodium vapor as the working fluid, and liquid sodium as the reactor coolant. The nuclear reactor would be at one end of the vehicle, crew's quarters at the other end.

The nuclear-powered, non-rigid blimp, designed by Goodyear Tire & Rubber, 1144 E. Market St, Akron 16, could become America's first nuclear-powered aircraft. The 540-ft blimp would be made of dacron, coated with synthetic rubber —capable of radiation exposures up to 100 million roentgens.

One advantage of the blimp, reports Goodyear, is that it can be fitted with a reactor with 1/20th the power needed for a nuclear-powered plane. Also, no elaborate ground handling equipment or special crew environment is necessary.

The blimp will be capable of 70 to 80 knots, and probably will use chemical fuel for takeoff and landing. The turboprop engines would be nuclear-powered only when airborne.

transportation

The Navy is building a rough road simulator to test how delicate electronic equipment withstands jouncing over rough roads. The simulator is an hydraulic-powered device designed by Commonwealth Engineering Co, 5725 Miami Rd, Cincinnati 43.

◀ General Motor's "automatic highway of the future" is an electro-magnetic system using a guidance cable in the pavement. Automatic control takes over steering, speed control, and obstacle detection. (GM Bldg, Detroit 2)

An atomic check system enables rapid, automatic counting and accurate identification of railroad cars, trucks, and other vehicles traveling in excess of 100 mph. The system embodies small radioactive sources, attached to the vehicle exterior. The source "patterns" are sensor-detected and then decoded. Development is a joint effort of U.S. Radium Corp, Morristown, NJ, and Electronic Assoc Ltd, Willowdale, Ontario.

A seat has been designed to prevent dangerous inhibition of blood circulation.

UCLA's Human Performance Lab says its new self-aligning seat incorporates a system of soft springs, "in constant, though barely noticeable, motion," which eliminates dangers of fatigue, fainting, thrombosis, "and even death(!)" Automobile application of the seat may prevent sluggish reflexes and occurrences of drivers "blacking out."

◀ In Germany, a completely enclosed plastic lifeboat, with two "bubble" observation domes, has been constructed to hold 40 or more persons.

The diesel-powered boat rights itself automatically from any position. Its submarine-like hull is glass-fiber reinforced polyester sandwiching foamed polyvinyl chloride.

chemistry

A plastic that won't burn—polytrichloropropene—when polymerized can impart flame-resistance to common plastics and, possibly, to other synthetic materials, such as rubber.

Applications of polytrichloropropene combinations may be fire-resistant paints, construction materials, fabrics, and rubber. The project, sponsored by Ethyl Corp, 100 Park Ave, New York 17, and Stanford Research Institute, Menlo Park, Calif, is especially significant because most other fireproofing methods require surface coating —which can chip or wear away.

A modified plasma jet is being considered for use as a high-energy source for spectrochemical analysis. The jet creates temperatures up to 8000C, producing spectra not obtainable at lower temperatures.

Designed at the National Bureau of Standards, Washington 25, D.C., the jet operates on a current of 15 to 20 amperes. In tests, the major constituents of stainless steel were determined with 2% variation.

Gyro-integrating mass flowmeter directly measures (in pounds) the mass rate of liquid and gas flow of any density. Its gyro motor and impeller motor operate from a common power supply, which can be unregulated with no effect on meter accuracy.

Developed by General Electric, 585-NR-1, Schenectady 5, NY, the flowmeter incorporates a flow-rate sensor, gyroscopic integrator, a fixed turbine, and a cyclometer register.

underground

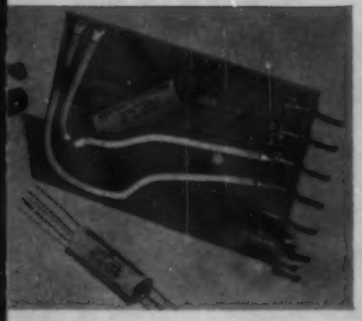
An unexpected boost for the American Miscellaneous Society's Deep Hole project "Moho" came from N.C. Dezendorf of General Motors—one million dollars in equipment will be leased to the project. Project Moho will explore beneath the ocean floor.

The offer was made at the Southern Research Institute's "Undiscovered Earth" conference last month, 2000 Ninth Av South, Birmingham 5, Ala.

Russia's underground project—the successfully-tested "burrowing rocket"—is planned for use in laying underground irrigation canals and pipes. However, U.S. experts doubt that the rocket outclasses America's fast cable-laying machinery.

The rocket nose has a pulverizing device containing liquid fuel and compressed air. Flames spouting from openings in the pulverizer open a path for the rocket. Some U.S. officials speculate that the rocket may be a further development of the 10-year-old "spalling" process (the use of flame to flake off rock).

now available:



◀ Ultra small, general purpose relay . . . The 3-gram "unimite" operates in one millisecond and requires about half the operating power needed for present crystal can relays. Developed by GE's Specialty Control Dept, Waynesboro, Va.

Mosquito "gas chamber" . . . Mosquitoes are attracted by a light, blown by a fan through a screen cone into a jar, where they are "executed" by sodium cyanide or paradichlorobenzene. Developed at Army Engineer Labs, Ft. Belvoir, Va, purpose of the trap is to sample densities of mosquito populations.

Rayon yarn for reinforcing mechanical rubber goods . . . "Super cordura" 272-F adhesive-finished, high-tenacity yarn eliminates the need for fabric dipping, thus decreasing inventory requirements, shrinkage, and processing costs. Produced by Du Pont's Textile Fibers Dept, Wilmington, Del, the yarn has a longer shelf life and greater adhesive retention than conventional fibers.

◀ Transistor phase comparison relay . . . Static protective relay is said to have wider application, lower maintenance, and faster speed that previously available models. Incorporating static components and small long-life transistors, the unit is used for protecting high-voltage transmission lines. Developed by GE, Schenectady 5, NY.

Magnetic field varied resistance . . . Electrical resistance is a function of an applied magnetic field in the "thinner-than-a-dime" MS-41 Magnetoresistor. Available from Ohio Semiconductors, 1035 W. Third Av, Columbus 8.

Motor drive amplifier . . . Designed primarily for tape recorder motors, the 35-lb unit has applications in fields which require extreme frequency regulation of the power source. Price is $1,350 from Precision Instrument Co, San Carlos, Calif.

Thermoelectric junction . . . Thermo-cell, TA-11, maintains a junction temperature above or below ambient. Designed by Ohio Semiconductors, 1035 W. Third Av, Columbus, the junction can be used for power generation and dynamic heat transfer.

Walnut-sized strobe tube . . . Applications of the FX-6A xenon-charged glass tube include stroboscopic studies, analog to digital readout, shaft position encoder, cold cathode switch, and microfilm recorder. Peak light output is 3500 candlepower. (EG&G Inc, 160 Brookline ◀ Av, Boston)

Small jet engine for short-range aircraft . . . The CJ-810, designed for commercial use, has about 8,000 lbs of thrust for 50 to 70 passengers. The engine will be capable of flying over 500 mph for a maximum of 1,500 mi. The CJ-810 will cost about $160,000 from GE's Commercial Engine Div, Cincinnati 3.

Plastic piston rings . . . The self-lubricating rings for compressors are long-lasting, withstand high pressures, and perform over a wide temperature range. Six plastic rings can do the work of 26 cast iron rings, reports Du Pont, Wilmington.

Sincerely,

F B Fragale

Assistant Editor
INDUSTRIAL RESEARCH

Stimulus to business planning:

basic research

BLUE-SKY PROFITS

On a dollar-and-cents basis, just what can industry expect from basic research, man's quest toward understanding the unknown? Just where are the profits?

RESEARCH BUSINESS VS. RESEARCH INSTITUTES

Conduct basic research to the exclusion of applied, or else pay taxes, say the research businesses. The institutes feel all research is too vital to industry to be curtailed.

THE MARTIN CO.'S WELLSPRING OF IDEAS

The Martin Co. has 50 top scientists working full-time on research that has no immediate payoff. Altruism? Take another look. Basic research is tomorrow's technology.

OUR NON-SCIENTIFIC GOVERNMENT

Scientists played a greater role in the U. S. government 150 years ago than they do today. There are reasons for this paradox, and some illuminating suggestions.

AROUND THE PLANT he was called the "oddball." The Iowa boy with the thin lips and high brow had left Harvard's faculty in 1928 to come to the du Pont Co. It was an unusual thing for a college instructor to do. At the same time, it was an unusual offer that industry had made: he could study any fundamental chemical problems he wished without regard for any immediate commercial objective.

The interest of the 31-year-old Wallace Hume Carothers was in the high polymers, the giant chain molecules. Polymers—because they were unmanageable, could not be dissolved easily or joined to other chemicals, and were almost chemically inert—were unattractive to most chemists.

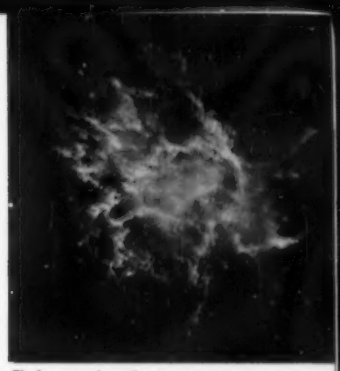
One day, one of Carothers' assistants dipped a glass rod into a still containing a molten polymer. As he withdrew the rod, the material stuck to it and stretched out into a long solid thread. To their surprise it was flexible and stretchable, even after it cooled.

Carothers immediately thought of refining the material for use as a fiber. This meant putting small "link" molecules of various combinations of nitrogen, hydrogen, carbon, and oxygen together and building up long chains that would combine and recombine to form the giant molecules he sought.

The chemical formula for the molecule he finally made looked like the product of a stuttering typewriter: $NH_2(CH_2)_6NH_2COOH(CH_2)_4COOH$—nylon, the first truly man-made fiber. Even more important, Carothers had provided chemists with an understanding of the giant molecules that made possible

From Scientists' Choice, Basic Books Inc.

Electron-microscopic photograph of zinc oxide.



Telescopic photograph of the Crab Nebula.

today's synthetic rubber and fabrics industries.

Nylon sales leap 13% every year

Nylon did not have the long wait for public acceptance that rayon did. In its first year, American women bought 64 million pairs of nylon hose. In one leap, nylon brushed silk aside as a competitor and stormed after other materials in uses ranging from underwear and pile furs to drop forge beltings, machine bearings, tugboat ropes and tire cords. In 1958 some 343 million pounds of nylon fiber were produced in the United States. At its 1958 growth rate of 13% per year, nylon production will be 560-million pounds in 1962.

Nylon also was the father of a score of new fabrics such as du Pont's Orlon and Dacron, Dow Chemical's Zefran, American Cyanamid's Creslan, and Union Carbide's Dynel. Sales of man-made fibers in 1955 accounted for 1.4 billion "blue-sky dollars."

Charles M. A. Stine, the man who hired the Harvard instructor, had called du Pont's investment in him "patient money." By this Stine meant that the giant chemical company was looking for no quick financial return on its investment in him. Actually, it was du Pont's vote of confidence in basic research.

There are many other examples of blue-sky dollars (see listing three pages hence).

How much money from basic research?

Today, on a dollar-and-cents basis, just what can industry expect from basic research, man's quest toward understanding the unknown?

An astonishing answer came from a study by Raymond Ewell of the National Science Foundation. He tallied up that part of the gross national product of 1953 that could be attributed to the discoveries of the previous 25 years and found the return was 100 to 200% a year for the entire quarter century. Stated another way, American industry realized $25 to $50 for every dollar it spent on basic research.

Yet, most companies do not appreciate this, as basic research accounts for only about 2.5% of total industrial R&D expenditures (according to statistics quoted by the National Science Foundation's Dr. Alan T. Waterman). Even the federal government—which actively publicizes the advantages of basic research through the NSF—spends only about 3¾% of its R&D funds in this area.

An outstanding example of industry-sponsored basic research is AT&T's and Western Electric's jointly owned Bell Telephone Laboratories Inc., which spent more than a billion dollars on R&D between 1900 and 1958. Probably about $150 million of this, or 15%, could be said to have gone into basic research.

Similarly, 15% of its professional staff devotes its entire time toward basic work. One scientist in this 15 percentile was William Shockley, of whom it has been said, "If you had suggested to Bill when he was at MIT that his interests in solid state physics might have a practical application, he would have been highly insulted."

Shockley left MIT for Bell not to enter commercialism, but to continue his fundamental explorations of the behavior of electrons in solids. There he was joined by colleagues John Bardeen and Walter H.

blue-sky profits

by **Theodore Berland,** *an I•R contributing editor*

Circle of progress illustrates with an example from solid state physics the complex interrelationships between basic and applied research. Starting at "11 o'clock" on the circle and moving counter-clockwise, basic, possibly "blue-sky," research was conducted on the energy levels and conduction mechanisms of solids. This study lead to an understanding of p-n junctions, which accelerated progress in semiconductor devices and lead to the invention of the transistor. (The circle has now emerged from the basic stage.) One of the first practical applications of transistors was smaller, more efficient hearing aids, a field which was approaching its limits under vacuum tube technology. From hearing aids, applied researchers utilized transistors and other semiconductor devices in communications equipment, such as radios and television sets, and also in computers. As the circle begins to close, feedback to the basic region occurs. In this sense, applied research begets basic research, although the flow from basic to applied is by far the stronger. For example, further basic research on energy levels, purification of materials, (continued below)

Brattain. The three-man team, concentrating on silicon and germanium, one day immersed a germanium diode in electrolyte (conducting fluid) that was connected to a source of d.c. current. Part of the current was being carried away by "holes," places where electrons were missing in the atoms near the surface. Brattain replaced the electrolyte with a metal contact, and transistor action was discovered.

200 million 'non-commercial' dollars

That was in 1948. In 1951 a variation, called the junction transistor, provided greater amplification and required less power. The first application was in hearing aids (1953), followed by the all-transistor radio (1955), followed by a $200 million a year industry in 1958, and by a predicted $500 million to $1 billion a year industry in 1965.

There are many who will argue that the transistor was as close to a deliberate invention as anything can be. Nevertheless, Nobel prizes are not awarded for inventions. Shockley, Bardeen, and Brattain got theirs for a significant contribution to science by explaining the behavior of electrons on the surface of solids.

Among other industrial giants heavily committed to basic research are General Dynamics, Westinghouse Electric, General Electric, RCA, Eastman Kodak, Union Carbide, Dow Chemical, Standard Oil, Continental Can, and General Mills.

But does basic research pay off for the smaller company? Ask Polaroid. The Polaroid Corp. is unique in that its president and director of research are the same man, scientist Edwin H. Land. Land speaking:

"A small company spending heavily on research can afford to change its product every few years to meet the demands of its market. As a result of the lavish expenditures in research, it can make for a few hundred thousand dollars enough machinery to produce many millions of dollars worth of its products. As its customers' requirements change from year to year it can afford to alter or discard this relatively inexpensive manufacturing equipment."

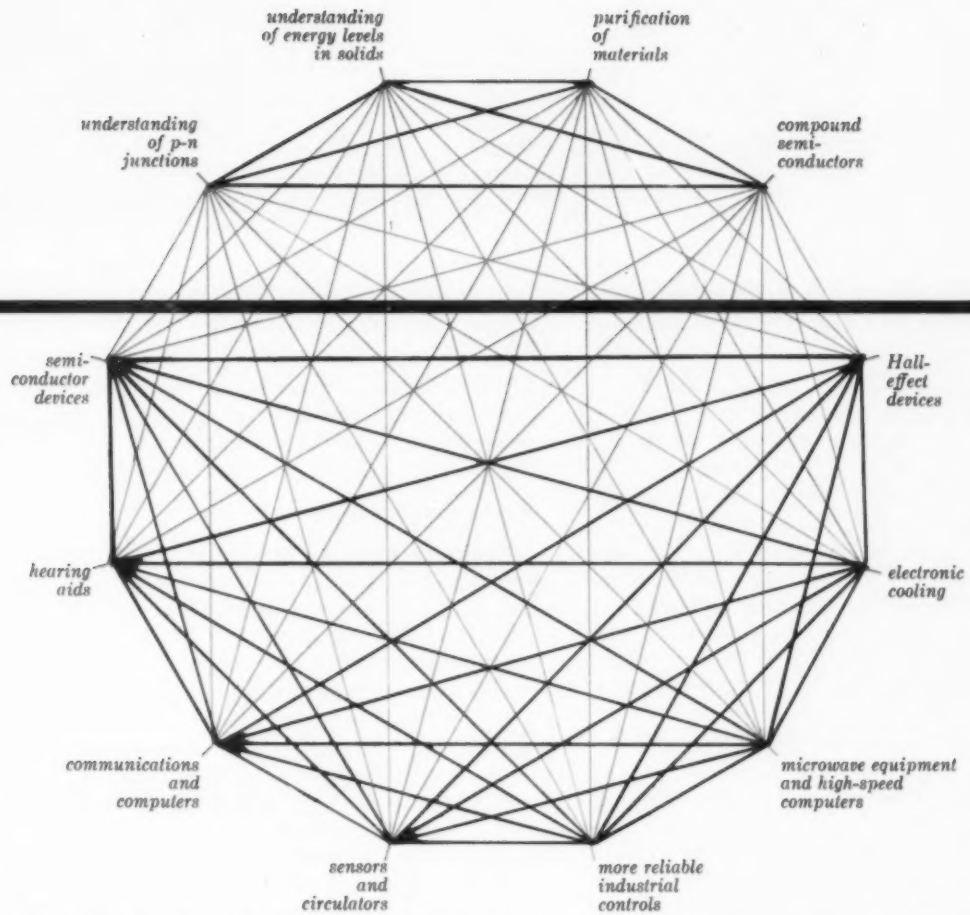
Before Land came up with the 60-second process for making pictures, in 1948, its sales stood at $1.5 million. Ten years later, sales had multiplied 43 times to $65 million.

True, this was not basic, but applied, research. Yet, as applied research often does (see "circle of progress" on the next page), the Polaroid work led to the purest of basic inquiries: how do we perceive?

The commercial spark that generated this fundamental question was Land's desire to invent a 60-second color film. In working on a single-process color film, Land went back to the basic work done by Newton, Young, Maxwell, and von Hemholtz. The story of his re-discovery is widely known. In 1955 he assembled a three-color projector used by Maxwell in which three black-and-white photographic slides, each taken through its own primary color filter, are projected through these filters to produce a full-color image on the screen.

One afternoon when only the red and green projectors were on, he removed the green filter. The screen flooded with white light that washed out the red image. Merö Morse, Land's associate, commented she could still see a variety of colors on the screen, although they seemed faint. Land's "conventional" explanation was that her eyes were experiencing the fatigue effect. You can get this by staring at one color, such as magenta, for several minutes. When you finally take your eyes off the color you "see" a phantom image in the complementary color, here blue-green.

and compound semiconductors (such as indium antimonide) is being stimulated by the practical need for more reliable and smaller industrial controls, sensors, circulators, computer components, and electronic cooling devices. The circle is not yet complete; the circle is never complete. Research, like success, leads to more research, both basic and applied.



That night Land couldn't sleep. His thoughts were on the pastel image his associate said she had seen. He dashed out of bed at 2 a.m., ran down to the laboratory, and repeated the red and white projection, this time dimming the white. On the screen was a full-color, lifelike picture!

Land's discovery launched him into a re-examination of how the eye perceives color. He found that if you project just two black-and-white transparencies —one exposed with a long wavelength of light and the other short—the superimposed images yield a full-color picture.

His explanation is that "the rays are not in themselves color-making. Rather they are bearers of information that the eye uses to assign appropriate colors to various objects in an image. The eye perceives color by comparing longer and shorter wavelengths. Therefore, color in natural images depends on a varying balance between longer and shorter wavelengths over the visual field."

Applications of Polaroid's new find

What are the prospects for Land's finding?

Since printing and photography are beamed at the human eye, it could mean an end to three-plus colors now used in full-color graphic reproduction. Color television, likewise, is a cumbersome affair in which each of three electron guns at the back of the picture tube fires at its red, green, or blue phosphor on the face of the tube.

BLUE-SKY DOLLARS

■ Radio and television are based on the 1864 theories of Maxwell on the nature of electromagnetic waves, the 1831 discovery by Faraday of magnetic induction, and the 1752 identity by Franklin of "positive" and "negative" electrical charges.

■ The 1935 invention of radar stemmed from the observations of E. V. Appleton in measuring the height of the "heaviside" layer by timing radio waves bounced back from it.

■ Today's liquid-fueled Atlas and Sputnik rockets

With the Land principle, only two phosphors and two electron guns are necessary, one for white, one for red.

Whatever the practical applications of Land's rediscovery, it has pointed the way to basic research, and this new fundamental work into how the eye sees may have far-reaching "useful" effects in entirely unforeseen areas. Basic discoveries are years ahead of their applications; in fact, Harold C. Urey's noted definition of the difference between basic and applied research is "20 years." Yet in our technological society, it is the applied research that so often begets the basic—a kind of mushrooming byproduct of the narrow application. Perhaps this is a fundamental difference between American science and European science.

Another example of how basic research followed application is the art and science of metallurgy. Age of Steel experiments have been based on a cookbook knowledge of the properties of alloy metals. Little work was done on the theoretical and basic studies into the nature of metals themselves, until the demand for stronger, more heat-resistant materials required a more fundamental approach. Now, theories are catching up to practice.

The alnico magnet is archetypical. B. D. Cullity of the University of Notre Dame wrote recently, "alnico (named for its constituents aluminum, nickel, and cobalt) was developed by men who used trial-and-error methods to push the art of making good magnets ahead of the theory of their behavior. Only recently, some 15 years after the invention of the alnico magnet, have the physics and metallurgy underlying the behavior of the alloy been worked out in any detail."

An example of basic metallurgy that has paid off is in the so-called high-purity metals, titanium and zirconium. Both were known for hundreds of years, but were not considered for industrial use because their brittleness and unductibility made them unworkable.

As new materials were sought to stand the blaze of rocket temperatures or the hammering of neutrons, basic research in the late forties revealed the source of weakness. The demon was impurities, such as oxygen, even in trace amounts.

A new way of looking at metal

A metal's purity is not the only influence on its strength. Theoretically, for instance, a piece of pure iron should be able to stand up to two million pounds per square inch pressures and bounce back to its original shape. Actually, the deforming point is only 30,000 pounds per square inch.

In 1934, G. I. Taylor in England and E. Orowan in Germany (now at Massachusetts Institute of Technology) advanced the idea that a metal's strength comes from the precise geometric construction of its atoms, called crystals. Weaknesses are the result of some imprecision in the atomic line-up.

Their concept led to one of the most promising and intensely worked on areas of metallurgy today, the dislocation theory. Scientists such as A. H. Cotrell of England showed that when a metal has enough dislocations, or atoms that have slipped from alignment, cracks develop. If the crack gets big enough, the material breaks, as occurred in the failure of Liberty ships during World War II.

Man had been improving the strength of metals for thousands of years by adding small amounts of other metals. But it was the dislocation theory which finally explained why. The "foreign" atoms simply fill in holes in the crystal latticework left by the out-of-place atoms.

Now the dislocation theory is more than an ivory tower pursuit. Again, Bell Labs, early in 1959, applied the concept in the manufacture of silicon for transistors. And the General Electric Research Lab-

"No research looks less 'functional' today than astronomy.' ...ss than a year

are the direct descendants of those developed in 1914 by Robert Goddard, a Clark University physicist.

■ The discovery by Harold C. Urey at Columbia University in 1932 of heavy water made possible the hydrogen bomb, at least one kind of nuclear reactor, and the search for controlled fusion power.

■ The organic phosphate insecticides are the result of basic research on the chemistry of nerve impulses in Germany in the 1930s.

■ The huge antibiotics industries are based partly on the discovery in 1928 by Alexander Fleming that something produced by a penicillium mold in a culture dish inhibited the growth of bacteria, and partly on the isolation of that something 10 years later by Howard Florey at Oxford University.

■ Inertial guidance systems, used to steer atomic submarines under the water and intercontinental ballistic missiles over continents, are a refinement of the gyroscope first tinkered with in 1810 by G. C. Bohnenberger.

oratory, by a technique in which material is "grown" with the help of electrical charges into long "whisker" filaments, has made a perfect silicon crystal larger than a man's finger.

Knowledge is application

"What is fundamental research today is applied research tomorrow. I believe in the end it will always turn out that way. I can think of no science, no line of research, that looks more 'fundamental' today than astronomy . . . the reason that astronomy seems to be so inapplicable is that we don't know all about astronomy. When we do we'll find the application."

Less than a year after these words were spoken in 1944 by du Pont chairman of the board Lammont du Pont, man's first atomic weapon melted the hot sands of Alamagordo, N.M. Samples of the temperatures and forces of dying stars had been duplicated by man for the first time.

The development of nuclear power, of course, from the discovery of radioactivity by Henry Becquerel in 1896 to Enrico Fermi's first atomic pile in 1942 to Alamagordo was entirely the product of university basic research.

Down the street from the Stagg Field racquets court where Fermi was leading a group of chemists and physicists towards man's first self-sustaining nuclear chain reaction, a small hook-nosed man was toying with a funny chemical element that behaved in strange ways.

20-mule team space rockets

The chemist was Hermann I. Schlesinger, a professor at the University of Chicago. The element was boron, the compounds of which are closely identified with 20-mule teams, water softeners, welding flux, and a mild antiseptic. While boric acid had been in use since the early 18th century and the element itself had been isolated in 1808, little was known of boron other than that its compounds did not follow the general rules of chemical binding.

In 1930, Schlesinger started his work on boron hydrides because "it was an area of chemistry that no one was exploring." He and a graduate student, Anton B. Burg (now a leading boron chemist on the University of Southern California faculty) developed a new method of producing 97% pure diborane gas. They also found why diborane was so hard to handle: combinations of impurities, such as other boranes, silicon and phosphorus, sparked unpredictable detonations.

Schlesinger's explosion-punctuated experiments opened the way to the development of a whole new field of chemistry. In addition to learning more about compounds of boron and hydrogen, he discovered a new class of boron compounds, the metallo-borohydrides, in which boron and hydrogen are joined by a metal.

Later he developed a technique now used industrially for producing tonnage quantities of sodium borohydride from methyl borate and sodium hydride. Metal Hydrides Inc., the nation's largest supplier of sodium borohydride, in May, 1959, celebrated the production of its first million pounds.

The major commercial use of this reducing compound is in the manufacture of such pharmaceuticals as cortisone, vitamin A, and antibiotics. Metal Hydrides provides upwards of 20,000 pounds a year to the pharmaceutical industry for these purposes.

In addition to its pharmaceutical uses, sodium borohydride is the key intermediate in the manufacture of boron-based high energy fuels (called HEF by the armed forces) now under development for rockets and jets. Metal Hydrides, Olin Mathieson, Callery Chemical (owned jointly by Mine Safety Appliances and Gulf Oil), American Potash, and National Distillers and Food Machinery all have

after these words were spoken, man had learned to duplicate the forces of dying stars.

Theodore Berland has been writing about basic research since his school of journalism days at the University of Illinois. He worked for the Champaign-Urbana (Ill.) Courier, *as a reporter and wire editor, and later flew for three years in the Korean War as a radar navigator and bombardier. Afterwards he edited a medical research magazine for Michael Reese Hospital, then became science editor for the University of Chicago where he edited the* University of Chicago Reports, *a monthly series of articles on new research discoveries. His stories ranged from Harold Urey's speculations on the birth of the universe to Leo Szilard's new mathematical theory on why we grow old. Berland is now a free-lance writer and contributing editor of I. R.*

boron fuel plants running at near capacity.

The exotic borane fuels at first are finding only military consumers. But one of the HEFs, a jet fuel, allows planes to fly a third farther than possible with conventional hydrocarbon fuels. Potentially, the jet airlines are large consumers.

Metallo-borohydrides are finding new uses all the time. In April, 1959, B. F. Goodrich's sponge rubber division announced to the industry that sodium borohydride and water in a slightly acidic medium was an unexcelled "blowing agent" for the production of foam products. The hydrogen released into such compounds as vinyl provides a superior foam with uniform cell structure, low density, and excellent resiliency. The process is particularly suited to the manufacture of small molded foam products such as sun visors, arm rests, and earphone cushions.

Thus Hermann Schlesinger's laboratory fiddling into a curious and explosive chemical provided a firm base on which a new chemical industry is being built. Did basic research pay off? The roar of a boron-fueled rocket screams the answer.

Profits from today's basic research

What profits of the future can come from today's probings of the curious in the basic laboratories. The executive's answer: "If I knew I wouldn't tell you. I'd put my money there." The scientist's answer: "If I had it in mind, it wouldn't be basic research."

Yet recent developments certainly point their fingers at the future:

- In chemistry the hottest area is biosynthesis, the discovery of the manufacturing processes of exquisitely complex substances by living cells. Each new find here has a potential application in medicine or agriculture. The hormone drugs, vitamins, and 2, 4D are examples.
- In the social sciences, the interest is in why man—particularly modern American man—does what he does. The applications in selling and promotion, as well as propaganda, are obvious.
- And physics has the solid state, which is leading to highly efficient masers (frequency amplifiers that can detect weak signals greater than any other amplifier, while their inherent noise generation is practically zero); electroluminescence (which promises thin panels of light and "picture-frame" TV); and thermoelectricity (which not only converts electricity to heat or cold, but also converts heat directly into electricity—and is being used in the Soviet Union to power radios in rural areas with the heat of kerosene lamps).

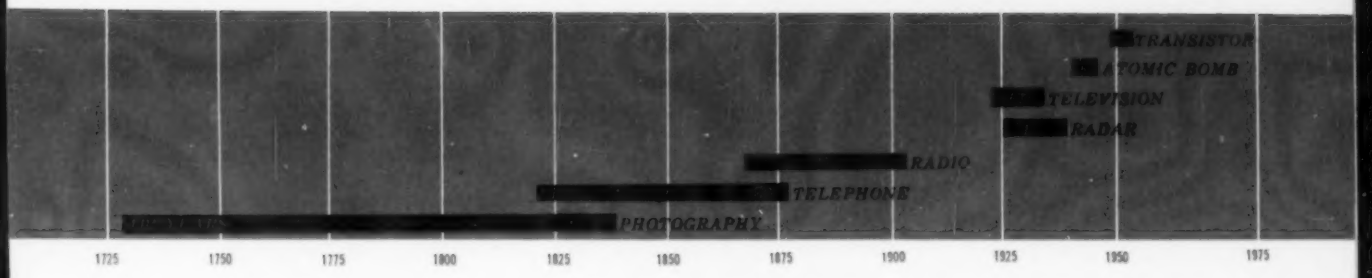
Taming the hydrogen bomb

Physics also holds the secret to taming the power of the hydrogen bomb. Many consider this science's greatest challenge in the coming decade. To achieve H-power means that nuclear reactions at 400-million degrees must be maintained and contained on a permanent basis.

It was a slight East Indian with a shock of unruly black hair dangling over his forehead who first set up the mathematics of the magnetism in stars and explained the structures and dynamics of stars on the basis of modern atomic theories.

He is Subrahmanyan Chandrasekhar, a scientist's scientist, little known outside of the University of Chicago campus and astronomical circles. It was only recently that he stepped down from the clouds of theory and rolled up his sleeves to help physicists and engineers at Los Alamos tackle the practical problems of controlling fusion.

The principle of controlling fusion is incredibly simple. You merely take two atoms of deuterium or "heavy hydrogen" and smash them together at terrific speeds to overcome their mutual repulsion. The result is the formation of helium and the conversion of a small amount of matter into a million times more



The decreasing time from basic discovery to commercial product

energy than is released in such chemical reactions as the burning of coal.

But the only practical way to give deuterium atoms the amount of speed required for "ignition" is to heat them to stellar temperatures. So far, these temperatures have been produced for any length of time only in the explosions of atomic bombs. That's why H-bombs need A-bombs to set them off. The problem is to contain the deuterium-helium gas reaction.

A key concept being worked on is the "magnetic bottle." The plasma (the high-temperature deuterium gas in which the nuclei and electrons have been separated) doesn't have to be in anything. It merely has to be kept together. The best answer seems to be to create a magnetic field to confine the plasma.

Estimates of the timetable of fusion control place it at 1965, with a pioneer fusion power plant ready by 1970 and economic fusion power 25 years later.

While progress is slow, industry is getting in on the ground floor. Princeton University's latest model "stellerator" is being fabricated by Allis-Chalmers Manufacturing Co. and RCA; General Electric and General Atomic each have their own fusion control programs, the latter at a new $10 million laboratory at San Diego.

The competition is international. Russia is slightly behind the U.S., and England slightly ahead. The British have reported maintaining ignition temperatures for a thousandth of a second, to our best millionth of a second.

"That, however," as Prof. Chandrasekhar said recently, "is like the man announcing his progress in learning to fly by flapping his arms: when he jumps into the air he remains off the ground for a thousandth instead of a millionth of a second."

In academic circles alone, the hottest area of physics is the so-called strange particles, the 30-odd bits of matter that are blasted from atomic nuclei by atom smashers. Physicists are curious about how these particles, called mesons, fit into the nuclear jigsaw puzzle. While they exist for but millionths of a second outside the nucleus, they are believed to be the "glue" that holds the nucleus together.

Another new idea in nuclear physics is the concept of anti-matter. Initial experiments on the 6.5-billion electron volt Bevatron at the University of California revealed the anti-proton. When an anti-proton meets a proton in the atom smasher, both are annihilated and converted into a tremendous release of energy.

Some scientists reason that if there is an anti-proton, why not an opposite for every particle known? And if anti-particles, why not anti-atoms? Astronomers are beginning to speculate that there are anti-galaxies out in space and when a galaxy such as ours meets one, the result is a cosmic catastrophe. There may even be an anti-universe to ours.

Support for this is the "right-handedness" of matter found in 1956 with the overthrow of the ages-old parity law, the accomplishment of which won the 1957 Nobel prize for Lee and Yang.

The matter-anti-matter release of energy is the only known 100% conversion of matter to energy. Those who have stuck their necks out the furthest propose harnessing matter-anti-matter reactions for power sources. Perhaps it can supercede fusion, after it replaces fission, which both convert only a fraction of a percent of matter into energy.

Will there ever be matter-anti-matter power stations? Who can say. Past experience shows that technological progress depends *primarily* on basic discoveries—such as Carothers' "impractical" work with inert polymers, Shockley's semiconductors, and Schlesinger's boron.

Their opportunities to do blue-sky research were unique. Management's courage in putting "patient money" on them was magnificent. So have been the profits from nylon, transistors, and rocket fuels. ■

"The non-profit institutes either should pay taxes or confine their activities to basic research . . ."

business V

There are two general, well recognized kinds of research. Basic research is sometimes called academic, pure, or fundamental, while applied research is known as industrial or business research.

Nobel laureate Glenn T. Seaborg, among others, has differentiated them: "The distinction between basic and applied research lies in motivation behind the research, the criteria applied to determine what work shall be undertaken, and what changes shall be made in the lines of investigation as the study develops. In basic research, the motivating force is not the attainment of utilitarian goals, but it is a search for a deeper understanding of the universe, and of living and inorganic phenomena, wherein its keynote is intellectual curiosity."

In other words, basic research is devoted to the exploration and development of fundamental knowledge, regardless of type and with no thought of exploitation of such research. In contrast, applied research is the systematic application of basic research knowledge to the commercial development of anything which may have commercial value now or later.

There is another critical criterion of differentiation. The results of basic research, except in those cases involving national security, are fully and immediately published for the benefit of the public, since they are not to be exploited for profit. In contrast, the results of applied research are almost always confidential and not published until the sponsor has had an opportunity to capitalize on his research advantages.

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by **Dr. Roger W. Truesdail,** *president, Truesdail Laboratories Inc.*

"Research is too important in our technology and educational system to limit it arbitrarily..."

Research institutes

a high-school boy piecing together parts of a discarded pinball machine, an outmoded radio, and an electric train to make his version of an electronic computer may establish an entirely new industry one day or become the key figure in our national defense. The possibility of this happening depends largely on his educational and research opportunities.

Research potential and productivity are similar to natural resources that are in short supply. Any arbitrary regulations or short-sighted customs that would prevent either a rare mineral or the unique ability of a researcher to be utilized for the benefit of the people of this nation can be justified only under unusual conditions.

Dr. Alvin H. Hansen, nationally known economist, asks: "What now are the real bases of long-term growth? The answer is scientific research and invention. If these can be made to grow at a more rapid rate than in the past, then we shall in the usual case be able to open up deeper and broader outlets for investments, and thereby accelerate the rate of long-term growth."

Research as a factor in our nation's security is so well established that it requires no verification.

Yet, demands are being voiced [ED'S NOTE: as in the "pro-profit" portion of this chapter] that this all important research activity shall be subject to controls. Some have urged that educational and other non-profit institutions confine their work to basic

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by **Dr. Clark A. Dunn,** *director of engineering research, Oklahoma State University*

Founder and president of Truesdail Laboratories Inc., a for-profit research laboratory in Los Angeles, Dr. Roger W. Truesdail has been a printer, editor, teacher, and researcher. He earned his Ph.D. in chemistry from the University of Washington, and taught at Mt. Angel College (where he was head of the chemistry and physics departments), the University of Redlands, University of Nevada, and the University of Southern California. He started Truesdail Laboratories in 1931, having built its staff to include 35 chemists, bacteriologists, and engineers. Truesdail has been active in the American Council of Independent Laboratories. In this capacity he has made numerous talks, including one before a Congressional committee on the theme that non-profit research institutes are in direct competition with research businesses.

Traditionally, we have relied upon colleges, universities, and non-profit organizations for basic or academic research. Industry has a vital stake in basic research since this research lays the foundation for the development of new products and processes. Many companies are allocating a share of their research dollars to basic research in their laboratories. Other companies support basic research in independent research laboratories, universities, and non-profit institutions.

However, the danger remains that the stream of research discoveries may run dry because of inadequate basic research. John Jay Hopkins, late founder and chairman of General Dynamics Corp., described this danger when he said, "Unless there is a revolutionary development in America of pure, not applied, science, there will come a day when there is no use in trading in your old car, because the new one is no better. The only difference between this year's television set and next year's will be the appearance of the cabinet! Scientific progress will be replaced by scientific stagnation."

Impractical as basic research may seem in its initial purpose, it is an essential prerequisite to applied research and product development. Frederick R. Kappel, president of American Telephone & Telegraph Co., in a booklet, *Business Needs Basic Research*, points out that the Bell System has been deeply committed to basic research. Such inventions as the "waveguide" and "pulse code modulation terminal" were born of mathematical thinking that started 30 years ago, and the "waveguides" of tomorrow are being born of new equations that men are laboring with now.

Are professors teachers or business men?

Dr. T. Keith Glennan, administrator of the National Aeronautics and Space Administration, has said, " . . . instructors are too often hired on the basis of their ability to attract research contracts. Separate research budgets — their attainment, fulfillment, and replenishment — occupies as much time and effort as the research itself."

Dr. Glennan continued, "The greatest impetus for this changed philosophy toward research on the part of most colleges has come from the availability of governmental support, largely, though not wholly, the result of technological demands of our defense program. At the time when the colleges were having difficulty in finding enough money to keep their good faculty members, the availability of these research funds was of inestimable value. To a considerable extent, this is still the case."

He concluded, "We cannot create genius but we can do a lot better job of encouraging its flowering if we regain once again the true spirit of creative inquiry on our campuses."

Prior to 1940 and World War II, little direct emphasis and even less outside support was given to research, *per se*, in most of our institutions of higher learning — other than perhaps in the fields of agriculture and medicine. In other words, there was very little, if any, applied research of the type carried on today by engineering schools or other departments of our technical institutes and some universities. Now many of our tax-free charter institutes of higher learning are involved in considerable industrial research for profit. To do so, they are neglecting their traditional responsibilities of properly educating the undergraduate student and supporting uncommitted basic research.

The National Science Foundation's publication, *Basic Research — a National Resource*, comments upon the change in philosophy of educational institutions toward research, "The importance of the university and college to the nation's advancement in basic research, and hence to the nation's progress through the benefits of research, cannot be rated too highly.

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Dr. Clark A. Dunn—as director of engineering research, professor of civil engineering, and administrative head of the school of general engineering at Oklahoma State University—is an authority on the relationships between research and education. In this article, as in his many professional activities, Dunn stresses the value of research in engineering education, believes it is of prime importance to the continued technological progress of the nation. Dunn's experience includes engineering bridges across the Missouri River, highway and bridge design in Arkansas, research in electric welding, and advisor to civilian and Army boards in Oklahoma and Alaska. He is a member of many committees, including the executive committee of the President's Conference on Technical and Distribution Research for the Benefit of Small Businessmen in Oklahoma.

research. These suggestions are based on the assumption that the non-profit institutions have an unfair advantage in competition for other research contracts because of their tax status.

Even if that argument were correct, it would be necessary to consider the effect on the nation's economy and security of confining research in non-profit institutions to the non-applied type. These proposals also assume that research can be classified easily. Attempts to classify the types of research have been only partially successful because definitions deal largely with the results of research and not research itself.

In the words of Dr. Clifford C. Furnas, chancellor of the University of Buffalo, "A research program usually starts as a gleam in the eye of the researcher. This leads to a certain amount of basic research which rises to a peak and then tapers off as the program advances. After a certain length of time applied research evolves."

Even if it were possible to select an acceptable definition of basic and applied research in order to delegate one type to non-profit and the other to profit-making organizations, such delegations would ignore the primary importance of the individual researcher to effective research achievement.

Research is only as good as the researcher

Accomplishments in either basic or applied research are dependent on the mental processes of individuals having unique knowledge, interests, and other special qualifications. It is illogical to delegate research responsibility on the basis of organizational structure rather than qualified people.

To deny non-profit agencies the right to perform applied research on the assumption that this constitutes unfair competition to the profit-making organizations could prevent the researcher most qualified from doing a given piece of research. The tax status of organizations seldom determines which is awarded a research contract if competent people are carrying on the negotiation.

Since research is so vital to our nation's economy and security and is so dependent on individuals of talent, our real problem is how to assure their maximum accomplishment.

There are two basic requirements to the maintenance of research accomplishment insofar as personnel are concerned:

- New research personnel must be developed at a rate and in a manner that will assure the continuation of the most desirable level of research activity.
- Research staffs must be placed in the most productive environment.

Industry must have a continued and increasing number of advanced degree men well grounded in their sciences and able to lead toward progress and profit for the companies employing them. The General Electric Co., for instance, predicts its needs for the next 10 years will be such that men holding doctorates will increase at least *twice* as fast as holders of BS or MS degrees.

The day is long past when the field of human knowledge was so small that an individual working alone could educate himself for responsible work in research, based as it is now upon increasingly thorough knowledge and efficient application of sound scientific principles. The responsibility falls upon the colleges and universities to develop research personnel.

With more than 25% of engineering graduates entering research and development organizations, superior research for advanced degrees has become essential for a reputable college level program of education in engineering. Another important consideration is that research activity has been demonstrated to be vitally important in influencing students to continue their education beyond the minimum four year program.

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This being the case, these institutions have a responsibility, generally acknowledged as one of their traditional functions, of maintaining high productivity of their research scholars and excellence in their scholarship. . . . Much of the applied research and development currently underway at educational institutions could be carried out effectively elsewhere, specifically in industrial and federal laboratories."

Dr. Fred H. Rhodes, former director of the school of chemical engineering at Cornell University, writes, "My greatest criticism of the American university education, in general, is the decreasing emphasis on really effective undergraduate instruction. There are several causes for this. One is the great number of sponsored research projects offered to and being accepted by the universities. When a sponsored research project is offered to a university, the usual immediate effect is the withdrawal of the most competent professor in that field from some or all of his undergraduate teaching so that he may be assigned to the project."

A half-million untaxed dollars

A subsidiary of a large university, a tax-free research institute, has conducted $75 million worth of business research upon 1,200 projects in the last 11 years. The *Wall Street Journal* commented thus: "Although it is a profit-making corporation, it does not pay taxes, because it is part of an educational institution . . . Its manager says its earnings are used to add new facilities and support fellowships. In its fiscal year, ended June 30th, the laboratory netted with no taxes, $429,000 on a gross of $13 million."

One university spokesman commenting upon research earnings of institutions of higher learning writes, "If all, or even a portion, of the always meager net earnings from such non-profit institutions were withheld for tax purposes, or if they were barred from tax-free corporate and individual grants, one of the most potent sources of advance on the part of many of the nation's most gifted scientists would be throttled."

A common justification frequently advanced by university representatives for accepting industrial research projects is that the work may lead to the production of a thesis for some graduate student. Thus, routine testing projects under contract long have been camouflaged as "research." The mere fact that a graduate student happens to be carrying out some routine testing procedure should not dignify the work with the term "research." Granted it might develop material for a thesis, but that still does not alter the fact the testing work is not research in any sense of the term.

Non-profit research institutes were created with very noble purposes under tax-free charters. In most instances, it was planned they would carry out basic research for the good of the public or they would conduct research on development of new products with such research results freely available to all. On this basis these institutes were properly granted federal tax exemption, as well as state, county, and municipal tax exemptions in some cases.

A 'public service' kept from the public

Almost without exception, they immediately went into the business of applied research, with little attention to their original purpose of basic research for the public good. The institutes have continued to devote the majority of their time, effort, and attention to applied research sponsored by industry, with the results of such research work held confidential and available only to the sponsor. In many cases this applied research has resulted in patents which are always assigned to the industrial sponsor.

The assistant director of one of the large research institutes in an address which was reprinted quoted a satisfied client of his institute as saying, "A unique feature of the services offered by these agencies lies

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Why do eminent scientists choose research?

In a pertinent five-year study, psychologist Anne Roe minutely examined the attributes of a group of 64 eminent scientists and the reasons why they chose their line of work. These scientists, selected by a panel of experts in their various fields, included 20 biologists, 22 physicists, and 22 social scientists (psychologists and anthropologists). While the results showed that there is no such thing as a typical scientists, still a common pattern of development emerged.

In their early years of college work, these men had no clearly defined vocation. Not until their junior or senior year was the decision to become a scientist actually made, and the decisive factor, almost invariably, was experience in research. Once the pleasure of this kind of work was discovered, there was no indecision, no turning back. In the actual words of two of them:

"I had no course in biology until my senior year in college. It was about my first contact with the idea that not everything was known, my first contact with research. In that course I think my final decision was really taken."

"One of the professors took a group of us and thought if we wanted to learn about things, the way to do it was to do research. My senior year I carried through some research. That really sent me; that was the thing that trapped me. After that there was no getting out."

With the knowledge that research has been so all important in the development of this representative group of men, once unsure of their goal in life and now acknowledged to be leaders in their fields, it becomes the obligation of educational institutions to provide such opportunity for students to sample the exhilaration of working at the edges of knowledge. Science is an endless frontier and students can best discover this through research.

There is a long and distinguished history of university achievement in the field of applied research which is a valuable byproduct of educational research. One institution alone, New York University, was instrumental in the development of both the telegraph industry, stemming from research performed by Prof. S. F. B. Morse, and the photographic industry which was largely influenced in its formative stages by Prof. Draper, who is credited with taking the first photograph of the human face.

More recent was the contribution by Dr. Salk, of the University of Pittsburgh, of the long hoped for polio vaccine.

Research is vital to teaching

Again to quote Dr. Furnas, who defined the situation at a research administration conference:

"After World War II, during which universities repeatedly demonstrated their facility for applied research, there were various forces that attempted to drive the university research function back to that of the good old days, to have them contract in size and scope. However, the universities did not do that. One reason for this is that research has been found to be necessary for good teaching."

The outgrowth of these and other similar considerations has been the adoption of a policy by the Engineering College Research Council, which says in part:

"The primary functions of a university are generally recognized as (1) instruction, (2) advancement of knowledge, and (3) public service. In an engineering school these three functions may be integrated to the advantage of students and faculty, the advancement of the art and science of engineering, and the welfare of the nation. The research program of an engineering

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The authors view the purposes of research

in the exclusivity of their relation to a sponsor. Not only do they honor the confidence that must of necessity exist between their staff and the sponsor, but to insure that a satisfactory atmosphere will be maintained, only one sponsor in a particular field will be admitted. The laboratories' work in this field, therefore, is available to him exclusively.

"This includes delivery to him of patent rights resulting from their work for him, control over the publication or dissemination of papers, data, or even reference to the nature of the work being performed for him." This research institute official concludes, "I believe you will find these comments are typical of those who work regularly with contract research organizations."

This perversion of their privileged tax status was brought out most forceably in *Research and Development by Non-Profit Research Institutes and Commercial Laboratories*. It was published by the National Science Foundation, compiled by a group at Syracuse University, and may be obtained from the United States Government Printing Office. This survey shows conclusively that research institutes devote only 6% of their activities to basic research or research for public good.

Institutes for profit — at public expense

The 94% is in the field of applied research, sponsored largely by industry or by a branch of government, with the results of such research and patents supplied only to the sponsor. Much of this 94% hardly can be classed as "for the good of the public." Yet strangely enough, *these institutes operate profitable businesses at public expense*. For any tax-exempt or tax-favored business costs every taxpayer more tax money.

Some of these tax-favored business operations advertise openly in newspapers that their services are available to industry. Some have outside technical salesmen. They are in the business of selling applied research. They issue expensive annual reports which shame those of many multimillion dollar corporations.

One research institute reported it had amassed $1.6 million for its equipment fund. It is difficult to imagine many tax-paying businesses which can amass that much for just plain equipment. This same report goes on to say a client is billed on the following basis: "The cost of salaries plus the overhead plus expenses, plus 12%" That 12% on a tax-free basis is a tremendously fine profit for any kind of a company.

An article, "Tax Crackdown," in *The Wall Street Journal* commented upon the growing number of tax-exempt organizations which are losing their tax freedom. "Two separate tax advantages are at stake. First, non-profit organizations are exempt from paying any tax on their own income. Second, many of these tax-free groups can solicit contributions with the powerful talking point that the gifts are tax deductible. . . . The Internal Revenue Service's efforts already have produced notable effects. So far this year, 47 organizations have lost the deductibility-of-contributions feature, compared with only 18 a year ago. . . . Others among the nation's nearly 150,000 tax-free groups will have to change their ways or lose their privileged status, Internal Revenue Service officials warn."

Who should conduct applied research?

Who can conduct the essential industrial research if educational institutions and research institutes return to their traditional obligation to do academic research? The obvious answer is the company-owned laboratory and the independent for-profit laboratory.

It has been estimated that there are approximately 1,000 independent tax-paying research, consulting, and testing laboratories in this country, staffed with more than 10,000 persons. These laboratories vary

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in education in two different ways.

school should properly embrace the following types of activities:

" ■ Research to discover basic or fundamental scientific principles and facts which will advance the science of engineering.

" ■ Applied research or development of specific devices or processes which will develop the competence of teacher and student, thereby serving the engineer in a manner parallel to the clinical studies of the physician.

" ■ Activities which serve the public interest, as for national defense, public health, or general industrial and agricultural progress."

This policy does not mean that all research projects will be desirable to further the educational objectives of a university or suitable for the public service goals of a non-profit research institute. Research suitable for an educational institution should be in the field of interest of the faculty member who himself is interested in that institution's educational program. Faculty members should be permitted opportunities to perform research, not only in the area of their teaching, but in related areas. Both basic and applied research are felt by various competent authorities to be valuable, indeed essential, in the education of students.

Let us look now at the other question involved in this discussion. This is the assumption that educational and other non-profit institutions have an unfair advantage in obtaining research contracts because of their tax status. This implies that, because of freedom from tax paying, these agencies are able to perform research at a lower cost and are therefore in a preferential position when contracts are awarded.

Contracts are not awarded because of price

Experience indicates that few if any research contracts are awarded on a price basis. Contracts are awarded primarily on the expectation of obtaining the desired results as quickly and accurately as the problem may allow. Remember that research is dependent to a high degree on the ability and interest of an individual uniquely qualified to perform such investigations. Competition, on the other hand, by non-tax-paying organizations solely on a business basis is seldom in the best interests of our economic system.

Bearing in mind that the research contracts are negotiated in many, if not most, instances because of an outstanding individual, there is seldom more than a cursory comparison between the prices that various agencies submit in connection with research contracts.

Here again the first inclination is to say that a given research investigation may be accomplished at a different price by different organizations. Actually research production or the research accomplishment will vary so widely that in no two cases will the result be comparable. Therefore the price is not comparable.

Industry can afford the best minds . . .

If research contracts go to the organization having especially qualified individuals, then it is quite obvious that the non-profit institutions do not have an advantage in securing research grants because of their tax status or any other status. The real advantage lies with the commercial organizations in this competition for research contracts, since the more flexible salary scales of these businesses should enable them to attract essential personnel.

Private industry, then, should be able to entice the best minds. Is this so in practice? Are the scientists in industry the leaders in their fields?

The surprising answer is "no" according to a study done by Francis Bello. He started out to identify a representative group of young scientists, those under

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greatly in size with some having staffs of more than a thousand and others with only several persons. Some have as many as a dozen branch laboratories. Several retain internationally known scientists as research advisors.

Not all independent laboratories do research and development. Some do testing, analysis, inspection, and sampling. The National Science Foundation has released a *Directory of Independent Commercial Laboratories Performing Research and Development*, which lists 565 tax-paying independent laboratories performing R & D.

Several dozen additional independent laboratories doing research and development were not included. The preface of the directory states, "The growth of research and development expenditures during the past decade has been many fold. The independent commercial laboratories engaged in performing research and development are utilized by numerous small firms, a few of the larger industrial firms, and by agencies of the United States government. . . . One hundred and seventy-five commercial laboratories reported research and development expenditures of $24 million. . . . "

The independent, tax-paying research laboratories can provide the same applied research services as offered by some universities and research institutes. They have scientists of equal quality, their research work is of equal quality, and their fees are comparable. They make a profit. They believe in free enterprise. They have never asked for tax favoritism and they believe in assuming the responsibility of their fair share of the cost of a democracy. But, they also believe in tax equality and fair play for all.

Research is as essential as accounting

Industrial research is an essential function that has been responsible for much of our industrial growth, the improvement of living standards, and the making of a strong nation. Results of such applied research are rightfully the property of only the sponsor. But applied research is as much a part of business operation as is any other phase; it is the private utilization of a professional service the same as legal or accounting services.

Industrial research is rightfully used for competitive advantage and cannot, under any stretch of the imagination, be considered a public service. How, then, can anyone honestly consider industrial research as anything other than a form of professional business which should be subject to all forms of taxation?

Research-conducting universities and research institutes can provide a valuable service to their community and to the nation, but they cannot do it by operating commercial businesses. I suggest they return to the field of basic research for public good — those responsibilities for which they were founded and which are needed so badly. Their tax-exempt status should be kept intact as long as they continue to do basic research with results immediately available to the public, except in those cases where national security is involved.

On the other hand, the independent laboratory profession should have no objection to having research institutes as competitors in the applied research field, providing they do not confuse the public by adopting the name of some university and providing they pay their fair share of the cost of government through equal taxation.

The independent tax-paying laboratories will continue to challenge the status of any tax-favored group which poses as serving the public without providing access to findings by qualified persons at all times, except those involving national security. ■

40, by asking for nominations of individuals thought to be the most promising both in industry and universities. Since it is the business of the foundations and the government agencies charged with awarding research contracts to know the top men in the various research fields, these foundations and agencies were asked for nominations. Names of 225 promising young scientists emerged. The investigator anticipated that the men would be about equally divided between industry and universities.

. . . but the universities attract them

Imagine his surprise to find only four of his 225 were in industry. Since he feared that his sample was too biased, Bello went to the directors of leading corporations and to top academic scientists, asking for nominations of any scientists in industry they felt to be top rank. Even after all this extra searching, only 35 names were listed for industry.

Yet, this high percentage of promising young scientists in educational institutions is not because the majority of scientists are in the universities. The National Science Foundation finds that private industry employs more than half of our scientists and engineers. Of 250,000 persons employed at the professional level in the *natural sciences*, more than 60% are employed by private industry, almost 20% by higher educational institutions, and nearly 20% by federal, state, and local governments. Of the estimated 700,000 *engineers* employed at the present time, about 75% work for private industry, about 20% for governmental agencies of various types, and probably 5% or less are employed by colleges, universities, and affiliated research institutions.

Clearly then, the small group in the universities and research institutes comprise some of our best talent. Why are these men here rather than in industry where their monetary return would be greater?

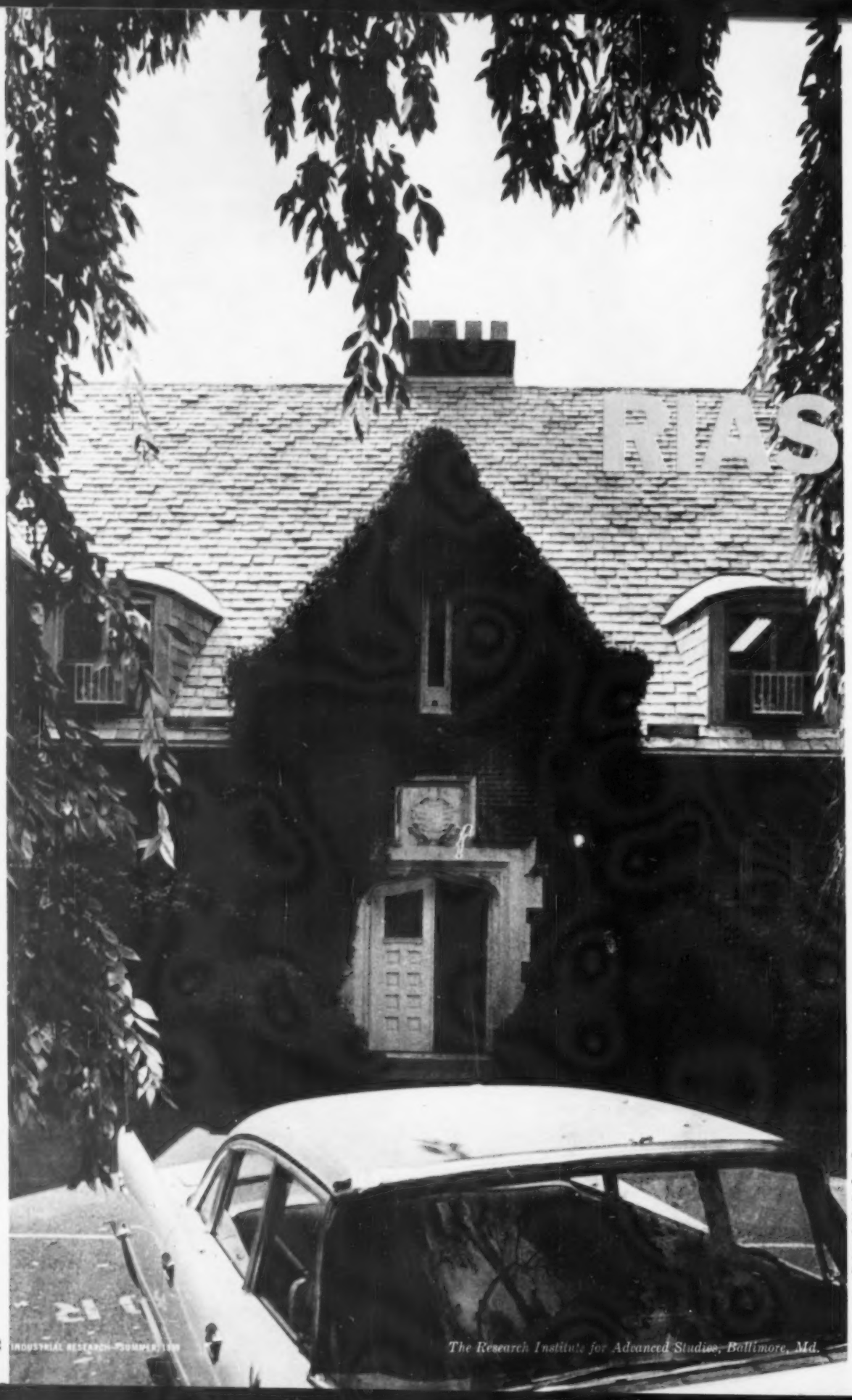
The research environment may be the reason. Research, being forever at the fringes of knowledge, finds virtue in activity that seems to an outside observer to be completely purposeless. Problems still hidden in the fog of human ignorance cannot be defined until clearly seen. Discovery has an accidental quality. The contact of a trained, alert mind with an unexplained phenomenon initiates that basic research that may lead to profitable applied research and development.

GE and Bell believe in idle curiosity

Two industrial laboratories do stand out as proof of the virtues of freedom of inquiry, not confined either to so-called basic or applied research. Of the seven industrial laboratories qualifying as having even one outstanding man, General Electric and Bell Laboratories had almost as many men nominated as the other five put together. These two laboratories have been the two outstandingly profitable ones, have consistently attracted brilliant researchers, and are precisely the ones that believe in idle curiosity.

Both kinds of research, basic and applied, are vital to our growing economy. It has become more expensive for industry to operate without research than to finance it, and this is a trend that will become increasingly evident as technology advances. Modern theories of employment or of industrial growth advanced by leading economists give a basically important place to research, listing it as a fundamental factor in our economy. Research is not optional today — it is a vital necessity.

Research, to be successful, depends upon the continuing supply of adequately prepared personnel. Since the development of a continuing supply of research personnel is almost entirely dependent upon the colleges and universities and their affiliated nonprofit research centers, these institutions must be free from arbitrary restrictions on the type of research they may accept. ■



The Research Institute for Advanced Studies, Baltimore, Md.

Photographed by Jon Pownall

Welcome W. Bender served as a key figure in electronics and design at The Martin Co. before the research institute was founded in 1955. Bender received his MS from MIT, then joined Martin in 1939. After serving as technical director of pilotless aircraft and head of electro-mechanical design for guided missile and fire control projects, Bender was charged with all aircraft electro-mechanical system development. From 1952 to 55, he served as manager of electronics. His long-time interest in basic research as a vital prerequisite to applied technology ideally suited him for the RIAS role.

by **Welcome W. Bender,** *director, Research Institute for Advanced Studies*

RIAS RIAS RIAS

the Martin Co.'s wellspring of ideas

During most any of these summers a balloon drifts in the upper atmosphere above Texas. Slung beneath it is instrumentation meticulously designed to gather information on particles of matter accelerating through the universe for millions of years, reaching nearly the speed of light, and developing energy as great as a million billion volts. These particles are heavy primary cosmic rays. They are best studied at very high altitudes where earthly matter and magnetic lines of force affect them least.

The scientists watching the flight and observing the telemetering data on the ground are authorities on cosmic radiation whose program was started by the late Dr. Gerhart Groetzinger.

The highly unusual, somewhat revolutionary fact about these basic research scientists is that they are not university professors working on spare-time "hobby" research. They are full-time, full-salaried *basic* researchers employed by American industry. They are staff members of the Martin Co.'s new wellspring of ideas, the Research Institute for Advanced Studies (RIAS).

These cosmic ray studies exemplify one of the charter aims of RIAS, simply "to observe phenomena of nature . . ." Under Dr. Philip Schwed, the launching of balloon and satellite experiments are part of a long-range attempt to add to man's meager knowledge about these cosmic particles.

One point that interests them is the possible presence of anti-matter, which destroys both matter and itself whenever the two come together. Another is the effect of solar activity on heavy primary radiation. Studying this effect may lead to understanding more about the processes of the sun itself, as well as the history and origin of cosmic rays.

RIAS was founded upon the conviction, first, that creative fundamental or basic research is a vital national resource and, second, that it must be considerably expanded on a broad, economic scale. Only in this way can science refill the reservoirs of unexploited scientific knowledge, being drained so rapidly by the nation's explosive technology.

Since its establishment in 1955, RIAS has attracted a staff of 50 scientists engaged in a diversity of fundamental research programs. Facilities of the institute are housed in three main buildings of a former estate in northern suburban Baltimore, Md.

As it explores new ways of accelerating the expansion of science, RIAS goes beyond the scientific community's traditional dependence on grants and endowments for support. Uniquely, it aims also to use some of the same principles of free enterprise, attractive to investment capital, that have made our nation's commercial and industrial growth vigorous and flexible.

Warburg apparatus is used in Martin's research institute for the chemical separation of plant cells.

Science—like art—for its own sake

Yet in its attitude toward basic research itself, RIAS believes in the classical tradition that science is served best by pursuing long-range learning for its own sake. It believes research of this type must be motivated by the curiosity of its scientists, unconstrained by any limitations or requirements for short-term practical applications.

This attitude is reflected in RIAS' programs.

A few months ago, a group of RIAS scientists published a paper describing a new method for crystallizing pure cholorophyll, the green pigment of plant cells. This is only a minor byproduct of something far more exciting: a broad inquiry into photosynthesis, the process by which all food energy and fossil fuel has been made and therefore the source of practically all usable energy on earth.

RIAS scientists, in short, are trying to do more than simply answer the famous question, "What makes the grass green?" They are making a concerted effort to explain the relationship between the molecular structure of leaf chloroplasts and the photosynthesis process itself.

Dr. Hans J. Trurnit, working in his laboratory at the RIAS mansion with films of materials only one molecule thick, is trying to find out why nature arranges its working materials in plants—the fats, proteins, chlorophyl, and water—in orderly layers. These layers can be seen under the electron microscope.

Proceeding from the theory that reproducing the subject in question will help explain how it operates, institute scientists are building film layers in controlled thicknesses. Using a precise ellipsometer, the thickness of these films can be measured to the order of dimension approaching one angstrom—one-hundred millionth of a centimeter, or approximately the diameter of a single hydrogen atom!

The shape of cancer, and gravity

This approach may or may not yield the secret of photosythesis in the foreseeable future. But along the way it is certain to broaden our understanding of the cell itself and its pattern of growth. Such studies also might help us understand cancer as well as provide the basis for further advances in computer technology.

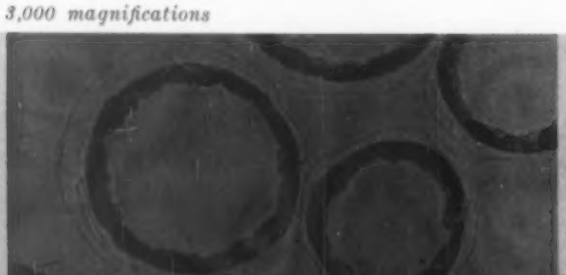
Nearby, in another of the informal RIAS offices, Dr. Louis Witten and his associates are making theoretical studies of the significance of Einstein's general theory of relativity relating to gravity.

According to this theory, the gravitational field is a measure of the deviation of space and time from the ordinary notions of "flat" space-time. Physical effects such as the gravitational attraction of the sun for the earth can be described geometrically. It is uncommon to describe any other physical effects geometrically.

Many years ago the mathematician G. Y. Rainich showed that general relativity also can give a geometric description to the existing theory of electromagnetism. Dr. Witten already is helping in the difficult task of verifying and describing Einstein's and Maxwell's combined theories of gravitation and electromagnetism exclusively in terms of the geometry of general relativity. While their mathematics is complex to the layman, it becomes obvious from a brief visit to a mathematicians' bull-session that researchers all over the world are well abreast of each other's progress and constantly are challenging each progressive step for hidden faults.

Searching for a fuller understanding of general relativity's implications may have no "practical" value in that it will lead to useful, everyday gadgets. This is not the purpose of basic research, though practical byproducts are well evidenced in the history of research. Pure science is "useful," however, when

3,000 magnifications



18,000 magnifications

RIAS scientist uses a Siemens electron microscope to examine chloroplast cells.

it helps unravel the mysteries of nature for no other reason than to unravel the mysteries of nature.

For example, the only known field in nature (other than gravitation and electromagnetism) represented as a particle of zero rest mass is the neutrino field. The time may not be very far off when a combined neutrino-gravitational theory can be described by geometry. If this description should become possible, it might give further meaning to both concepts. Scientists always have been conservative about predicting what such a description might lead to, but an understanding of the many strange particles some day could lead to practical uses.

Basic discoveries in metallurgy also have been made at RIAS. Dr. Howard Peiffer recently has been researching the physical characteristics of an ingot of soft material such as silver, in which a relatively few tiny particles of very hard refractory materials have been dispersed. In his studies he has been measuring some unusual strength and hardness properties that suggest applications in electrical contacts. Trying to understand the reasons for this behavior, Dr. Peiffer has discovered quite inadvertently that *the silver base material is still quite viscous even when heated well above the melting point of silver.*

This characteristic was quickly noted by the brazing industry. It solves certain difficult problems of brazing curved surfaces. How? Being viscous, the dispersion-hardened silver produces a uniform fillet, whereas conventional silver braze materials run out of the joint.

Byproducts are only byproducts

Now, such fruitful byproducts might result more frequently from metallurgy than from relativity physics. Yet the value of true basic research cannot be measured even by such immediately useful byproducts, any more than a university can base its contribution to the world on the numbers of patents held by its faculty. When strong efforts are made to direct research toward the practical, history shows that the long-range studies succumb to the short-range. Note how applied metals research is thriving, possibly at the expense of long-range effort in relativity physics.

These examples may be extreme, but they point up the conditions which motivated the Martin Co., a developer of aircraft, guided missiles, and electronics, to establish a basic research institute. RIAS is chartered to explore nature, rather than focus on short-range or applied research. Martin management feels that industry already is highly motivated to pursue applied research.

Some five years ago, George Trimble, now Martin's vice-president of engineering and director of the spaceflight division, became deeply concerned about the apparent decreasing supply of new, fundamental ideas to nourish the appetites of the company's development engineers.

Trimble then was responsible for Martin's advanced design activities. He was chronically disturbed that company efforts lacked enthusiasm and appeal, and felt the prime reason was a dearth of new ideas. Design projects at that time might have involved nominal state-of-the-art improvements, but new underlying concepts were rare and growing rarer. The ratio of new ideas to the number of engineers seemed to be falling. Something was wrong. The subject was discussed frequently around the company, and gradually an alarming picture began to emerge.

Soon it was apparent, though, that the situation bothering George Trimble wasn't confined to the aircraft industry. In past decades, and especially since the beginning of World War II, our technological activities have been growing very rapidly; all our

25,000 magnifications

Under electron magnification, the seat of photosynthesis —chloroplasts—can be seen. Chloroplasts in the middle and right photos correspond to the prune-like forms in the lesser magnification at far left, which shows complete plant cells (of spinach leaves).

A variable-speed flashing light source fabricated at the RIAS laboratory is designed to supply measured amounts of light to plants in photosynthesis experiments.

industries have become more technically oriented. But at the same time, the sources of new knowledge, primarily the university research laboratories, have not been able to expand their basic research activities fast enough to keep pace. Aircraft firms and many others have been pushing technology to the limit, repeatedly meeting problems unanswered in any existing scientific literature.

A way out . . . an aggressive way

RIAS was proposed to the Martin board of directors as a way out of the dilemma—as an attempt to expand basic research via the same economic principles that built our national technology. This is in sharp contrast to the traditional attitude that pure science must hesitate at the doorstep of the economy, quietly awaiting the charity of endowment. The board enthusiastically endorsed the RIAS concept.

Since basic research, by definition, cannot predit its own usefulness, it follows that it is impractical to pick one research field as more important than another. RIAS' founders therefore decided to select *talent* first, despite the definite possibility that random studies would result.

The universities' stake in basic research

At this point, the question may persist, "All well and good—but wouldn't it be better to leave basic research to its traditional, proven wellspring: the university? Does it make sense to start a new, untried approach? Surely, the transfer of a scientist from a university to RIAS will hinder basic research by removing a man from the profession which trains our future scientists."

Perhaps a defense can be made with a key example.

About a year ago, under the direction of the world-famous mathematician, Dr. Solomon Lefschetz, a center for the study of nonlinear differential equations was established at RIAS. The program was stimulated by Dr. Lefschetz' concern about the relative neglect of this important field of mathematics in the Western world plus his close realization that substantial progress was being made elsewhere, especially in Russia.

Nonlinear differential equations is certainly a field offering broad implications for control systems, automation, and all sorts of regulators which, for lack of better methods, have been oversimplified by assuming linearity. More and more, especially in the biological sciences, we're aware that nature takes great advantage of *non*linearities. Most man-made devices handle nonlinearities either empirically—or shy away from them entirely. Yet with more progress in fundamental mathematics, designers doubtlessly will gain increased confidence to use nonlinear approaches in their original designs.

The nonlinear equation group at RIAS now includes 15 very capable mathematicians, all working in the same general field. Already they have noted the stimulus of their own interaction of ideas. Several, like Dr. Lamberto Cesari of Purdue University, spending a sabbatical year at RIAS, are eminent teachers. Others are young mathematicians with promising talents for research, but less appetite for teaching undergraduate courses. A number are mathematicians from industrial concerns who find basic mathematics far more exciting and rewarding than the applied problems of industry.

Why not a university RIAS?

Why hasn't such a project started in the universities? The answer involves at least two substantial rationalizations:

First, most of our universities must support a broad teaching program in mathematics and cannot justify a concentration of more than two or three staff members in a special field. The tendency then

Hallway discussions are commonplace in the informal RIAS atmosphere —a basic to basic research.

is for qualified scientists to gravitate toward applied research in industry.

Second, investment capital for such an enterprise has not been available, and there is little enough endowment capital to pay its present commitments.

Endowment support is inherently static. It does not allow the large-step growth visualized at RIAS. But even if the universities had the funds, such concentrated research might begin to unbalance the primary teaching responsibilities. So, the university environment often passively or unwittingly discouraged such pin-pointed basic research.

The fact is that at least two previous attempts to found such RIAS-like groups at different universities have been unsuccessful.

Dr. Harold Gershinowitz, president of Shell Development Co., writes in *American Scientist:*

"It just isn't possible that enough work can be done at universities even if they did all fundamental research and no applied research."

The alternatives to limited endowment capital are either public funding or private capital with income paid by a customer. In the sense that truly basic science falls in the public domain, its nourishment becomes the concern of government.

Industry, as a consumer of knowledge, is expected to contribute to basic research, and, of course, much fine work is financed this way. But since industrial income usually depends on better hardware, the pressures are strong to spend research funds on applied, not basic, research.

The Institute's approach is to retain the flexibility of private enterprise working for a return on investment while remaining independent of hardware profits for sustenance. This bypasses the usual and so often overpowering pressures toward applied research. Recognizing the value of scientific inquiry as a major national resource, RIAS seeks government contracts for basic research directly, at actual cost (including a return on investment capital). In this way the time and expenses of qualified researchers would be supported by contract and not hidden, for instance, in product overhead, nor rationalized in foreseeable product economies.

Profits on nonlinear equations

There seems to be no real difference in principle, between making a return on capital invested in developing an earth satellite and in making a return on similar capital invested in offices and salaries for a group of mathematicians creatively studying nonlinear differential equations. Neither has any real product significance, yet both are excellent national investments in the future.

In addition, RIAS or any independent laboratory, unlike a government laboratory doing the same work, is in a position to help make the nation basic-research conscious in these critical times. Economists would call it "advertising" or "developing the market."

The approach being tried at RIAS is only one attempt to find a way to expand basic research. It may not be the best one, but in its first few years, it has progressed encouragingly. If any of its experiments leads to increasing the flow of knowledge to technology, the institute's work will have been well worthwhile.

Dr. Lawrence Hafsted, vice-president of research of General Motors Corp. sums up the picture concisely:

"Engineering is the exploitation of science. To be successful, it must be given some science to exploit."

If industry is to have a virgin crop of ideas and techniques to harvest tomorrow, basic science must discover and sow them today. In this year, in the United States ofAmerica, this is the vital husbandry of RIAS. ■

Miniaturized telemetry equipment for measuring cosmic rays is to be installed in a satellite.

Our non-scientific government sits in a special joint session of the 86th Congress in the crowded House chambers. Representatives and senators total 534, but of them only 14 have scientific or semi-scientific backgrounds: four were physicians, three pharmacists, one a high-school chemistry and physics teacher, three engineers, one an industrial chemist, and one a mathematician with a Ph.D. from Cal Tech (D. S. Saund, democratic representative from California). One of the pharmacists—Carl T. Durham, democratic representative from North Carolina —at least got to represent "science" in government; he was a vice-chairman of the Joint Committee on Atomic Energy. The Soviet science scare had no appreciable effect on the representation of science in government. In fact, the number of scientists in Congress seems to run in inverse proportion to the technological nature of our nation. The preceeding Congress scored 12 scientists. Thus, 1959 and 1957 = 3% and 1776 = 11% scientists in Congress.

I·R contributing editor, Dr. Joseph W. Still—
director of the Bucks County (Pennsylvania) Health Department
—is a working physician-scientist.
His research on the chemistry of aging,
conducted at George Washington University School of Medicine,
has attracted considerable interest in scientific circles.
As a Lieutenant Colonel in the Army Medical Corps,
Still participated in many of the dramatic medical advances
made in the Mediterranean theater.
In this article, as in his book,
"Science and Education at the Crossroads,"
Still offers a critical examination of American science policy,
and proposes some bold new solutions.

by **Dr. Joseph W. Still,** *an I·R contributing editor*

non-scientific government

When we examine the history of science and government in the United States we discover a remarkable paradox. Scientists actually played a relatively more important role in the early affairs of our government when we were a weak agricultural nation than they do now. It may be useful to consider why this is so: to consider some of the adverse social-economic consequences of this situation, and what might be done to reverse it.

Since the birth of the Italian Renaissance in about 1450, there has been an accelerating growth in scientific knowledge. Naturally, the earliest scientific work was predominately basic in character. It wasn't until 1750 (about the birth date of the Industrial Revolution) that important applied uses of scientific knowledge began to be made. A time lag of 300 years apparently was required before there was enough basic data available so a "chain-reaction" of applications could begin.

A similar situation seems to occur in the mental development of a young child. Until a certain level of information has been acquired, very little interaction (thought) occurs. But once the critical level is attained, an "explosive" chain occurs. The Industrial Revolution seems to extend this principle on the social scale.

So we may identify two major phases in the growth of science. For 300 years science was accumulating a body of basic information and for the last 200 years men have been finding more and more ways of applying basic knowledge to make useful things and thus to make money. Only recently have we begun to appreciate this fundamental value of basic knowledge and to reach the stage of being willing to subsidize basic research.

Ben Franklin's part-time kite

It is important to remember that until about 100 years ago, there were almost no full-time professional scientists—only wealthy devotees or part-time hobbyists. But many of these were very capable despite their amateur status. Ben Franklin's kite experiment, in which he showed that lightning is due to an electrical discharge, is a perfect illustration of a first-rate experiment by a part-time amateur.

Strangely enough it is the transition from a part-time to a full-time role that has downgraded the role of the scientist.

Gradually, with industrial growth and with the accumulation of wealth, a few men began to make science a full-time pursuit. But aside from the few who were supported by patrons, only the well-to-do could afford a way of life that brought no income. Who-done-its and crossword puzzles had not been invented yet, and so basic research was something of a diversion, as well as an occasional occupational necessity for teachers, druggists, farmers, physicians, engineers, and others.

Our well—
of fundamental ideas—
is going dry
with applied researchers
tapping it relentlessly
and with only
a comparatively few
basic researchers
replenishing it.
Fewer than 30,000,
or 4% of U.S. scientists
and engineers,
are at work today
on basic research.
Legislate against it?
Hardly.
The government
is non-scientific.
Author Still calls
for a minor
reorganization
—the establishment
of "secretaries
of basic science"
—as the first step.

This state of affairs was possible because most important scientific questions could be investigated with very crude instruments. The body of accumulated knowledge was so relatively small that it was not too difficult for a well-educated person to have a good basic understanding of all areas of science.

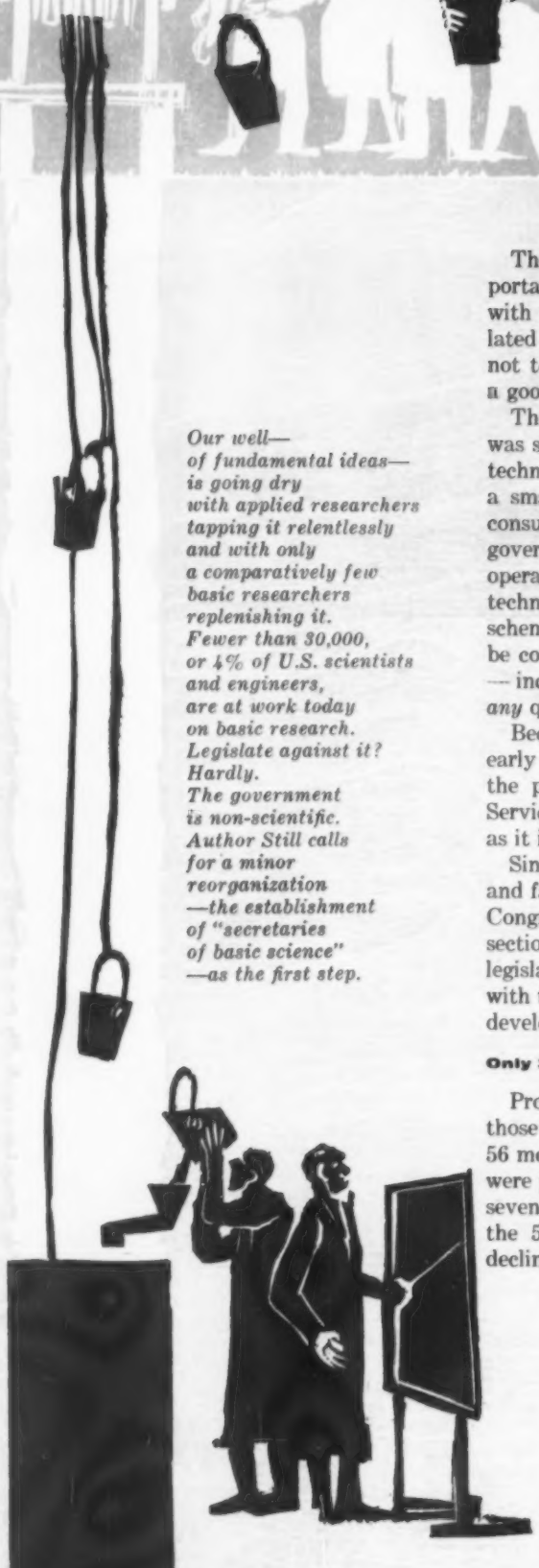
The United States was established while science was still in this "do it yourself" era. Specialism and technology hardly had begun in 1776. Consequently, a small number of men without benefit of special consultants could operate a business, an army, or a government. They could establish policies and plan operations with little fear of overlooking some obscure technicality which might disrupt a whole elaborate scheme. Any small group of well-educated men could be counted on to know most of the important facts — including scientific facts — needed to solve almost *any* question.

Because of the relative technical simplicity of our early economy and of early American life in general, the problems of government were simple as well. Service in the Congress was a part-time task, much as it is still in most of our state legislatures.

Since it was part-time, many teachers, physicians, and farmers could be and were members of the early Congresses. This situation allowed a broad cross-section of community life to enter into the national legislative halls. These part-time legislators brought with them all the science of their time, relatively undeveloped though it was.

Only 3% of Congress have scientific backgrounds

Proof that science was far better represented in those early days is found in the fact that six of the 56 men who signed the Declaration of Independence were physicians (11%). By contrast, there were only seven physicians and pharmacists combined among the 534 men in the 87th Congress, an eight-fold decline. There also were only one mathematician,



one science teacher, and three engineers in the 86th Congress, making a total of 14 scientists. This is less than 3% of the total. Can anyone believe that this was a proper representation of scientific thought in the year 1959?

As legislation gradually became more time-consuming and finally became a full-time job, practicing scientists, physicians, engineers, and teachers have been represented less and less in Congress. This has happened because even one "full-time" term in Congress would leave a scientist, physician, or engineer so out of touch with his special field that his professional competence would be damaged. The result of the shift from part-time scientists, who also were part-time legislators, to full-time scientists and full-time legislators has been to leave the legislature almost entirely to lawyers and businessmen who now completely dominate Congress.

This shift in the makeup of our Congresses has occurred quite rapidly, historically speaking. Science as a full-time occupation in which to earn one's living did not really begin on any important scale until the late 19th century. Louis Pasteur in France and Thomas Edison in the United States were among the earliest full-time scientists who did not have independent incomes. These men were among the early pioneers who showed that basic science was a tool for manipulating nature, a tool which could be applied to make wealth.

Europe's eggs have hatched in America

Because our national status began less than 200 years ago, science, from its inception, has meant only technology to most Americans. Our overemphasis on technology and our ignorance of the role of basic science which underlies it was possible only because there existed an abundant pool of basic information available to our industries without cost. And this information was "free" only because Europe, over the preceding centuries, had produced most of the basic discoveries on which our technology has been built. In short, Europe laid most of the eggs but we got a large share of the chickens that hatched from them.

This situation has had much to do with the fact that, until recently, government and industry in this country have been more interested in promoting inventions than in fostering fundamental ideas and research. Since no price-tag could be placed on basic ideas and since we hadn't even had to support most of the men who made basic studies, their value was not appreciated.

There are other historical reasons for the relative over-emphasis of technology in our country. We not only had free ideas, but we had a continent full of free natural resources. We were even able to import millions of trained and educated adult workers from other countries — also at no expense.

None of this is said to disparage the sacrifices of our pioneers or to criticize them for not setting up a Plymouth Rock Research Foundation as soon as they landed. These are only reasons why our nation does not place a higher dollar value on basic science, and why today we do not make greater use of the wisdom of our scientists in the policy-making levels of government and business.

I have given statistics to show how poorly science is represented in Congress. But I can go further and say that basic science today is grossly under-represented at the policy-making levels of almost all aspects of government — as well as in private business and labor.

In the top echelons of our government, basic scientists merely serve as technical consultants who answer the questions posed by non-scientists. Scientists are almost completely excluded from *asking* questions in policy-making roles, for they are seldom present at the discussions.

A U.S. secretary of defense has said that someone other than the military

The disclosure that Mrs. Oveta Culp Hobby, former Secretary of Health, Education and Welfare, set a deadline of 75 minutes on the committee trying to decide whether or not to release the Salk vaccine clearly demonstrates her ignorance of the scientific decision process.

By and large, non-scientists can recognize a scientific "trouble spot" *only* when it has become a fairly obvious one. This is not said in criticism of non-scientists. It is simply a fact which derives from the nature of specialism. Because science is so poorly represented at the planning and policy levels of present-day government and most businesses, the science aspects of many matters are too often too late in being recognized.

Vanguard of world opinion

There could be no clearer proof of the government's scientific ignorance than the mishandling of the first Vanguard satellite firing. If scientists really had been in complete control of this project, there would not have been the psychologically stupid publicity buildup.

As a tool of the publicists, the experiment placed those in charge of the satellite launching under terrible pressures which have no place in a scientific laboratory. It is unfortunate that the scientists did not refuse to operate under these circumstances. Their failure to insist that the experiment take priority over the publicity embarrassed themselves, our science, and our government.

Only science's lack of status permitted the continuing nonsense of publishing on-the-spot reports of every launching — time after time, until finally the public itself grew weary of the "failures." By their very nature most tests are bound to fail in the newspaper sense of the word, though not necessarily in the scientific sense. Because of the government's ignorance of the nature of science, we have been treated to the ridiculous argument that we are proving how "democratic" and free our press is by reporting these "failures." The fact that the circus atmosphere resulting from this news reporting actually helps to insure "failures" has not been considered.

The whole situation makes it abundantly clear that scientists are not in charge of rocket launchings. For no scientist would of his own volition hamper his chances of success by permitting the amount of press coverage and resulting psychological tension that result therefrom.

When President Eisenhower called his first large-scale conference to consider the strategic implications of Sputnik, not a single working scientist was present among the 30-plus men in attendance. This clearly indicated the measure of science's role in the White House at that time. President Eisenhower's subsequent appointment of Dr. James Killian, dictated to a large extent by public relations motives, has not increased the role of science spectacularly.

Although several agencies have been formed since to strengthen our space and rocket technology (such as the National Aeronautics and Space Administration), none of them has the authority and prestige needed to enable scientists to exert the role in government which the importance of science justifies today.

To show another unfortunate effect of our non-scientific government, consider science's role in perfecting new tools of life. DDT, penicillin, and polio vaccine are the best known tools, but there are numerous other human, animal, and plant disease-control methods recently perfected.

Without question, these public health tools have played *the* major role in setting off the "population explosion" which began at the end of World War II. It is the explosive force of hungry but *healthier* people *increasing at a rate faster than their economic productivity* that needs to be understood if we hope to live on the same planet with Nasser, Nehru, and their

should carry on fundamental research as to what makes the grass green.

The "green-grass" thinker may not be the answer to all industrial and governmental problems. But his opinion in this age of science is too important to have it play only a secondary role.

followers. If our policy-makers included some biologists, they might spend more time analyzing the public health of Egypt and India and less analyzing Nasser's and Nehru's psychology. In that case we might gain a better understanding of what makes Egypt and India run as they do rather than as we wish they would.

This is not to suggest that the opinion of science should settle every issue. But science is too important today to have it play only a secondary role.

Only a few weeks before Sputnik, Secretary of Defense Charles E. Wilson made a remark which seemed to indicate a complete lack of appreciation of the value of basic research. He said that someone other than the military should carry on fundamental research "as to what makes the grass green." One can suspect from this remark that Secretary Wilson had never heard of the flow of solar energy to automobile power via green grass and gasoline.

The reports of the Fairless and Rockefeller committees, both containing a predominace of businessmen, also illustrated how businessmen tend to overemphasize "hardware" technology and under-estimate "green grass." Up to a point, their emphasis on hardware is certainly understandable. People know most about the field in which they specialize, and businessmen specialize in "hardware."

But the point is that such committees usually contain few if any working scientists, and that every important group in our society should have an influence on such committees and on national policy if we are to have well-balanced, soundly conceived policies. Basic science (and education) are not so represented today and the nation is the poorer for it.

Death is priced higher than life

The operational version of our prime question is this: Why is it that engineers working in weapons development—applied necrology, if you will — can

command salaries considerably higher than the basic scientists who provide the knowledge upon which our civilization is built, and our lives are extended?

What explains these misplaced values? Why have our leaders failed to note how poorly basic science, biological as well as physical, is represented in the upper levels of government? Why have there been no efforts to create prestige positions in the Cabinet and Congress to be held by scientific leaders? As outlined earlier, the historial answer is that we have undervalued our "free" basic science. Today, we are still undervaluing it.

Corrective measures

How can we correct the situation? These are my suggestions:

The President should appoint one or more "secretaries of basic science," without portfolio. Probably there should be at least two, one representing basic biological and one representing basic physical science. The two fields of science are sufficiently distinct to justify separate secretaries. The other secretaries of the cabinet also should consider the desirability of strengthening the representation of both basic and applied science on their own staffs.

Congress should establish delegate senatorships and representativeships, essentially as has been advocated for ex-Presidents, and as U.S. territories are represented currently.

Such scientist-Congressmen should have the power to introduce legislation and enjoy full floor and perhaps limited committee privileges. These posts might be held by the presidents of major scientific organizations, but it would be better still if scientific bodies elected specific representatives to fill them.

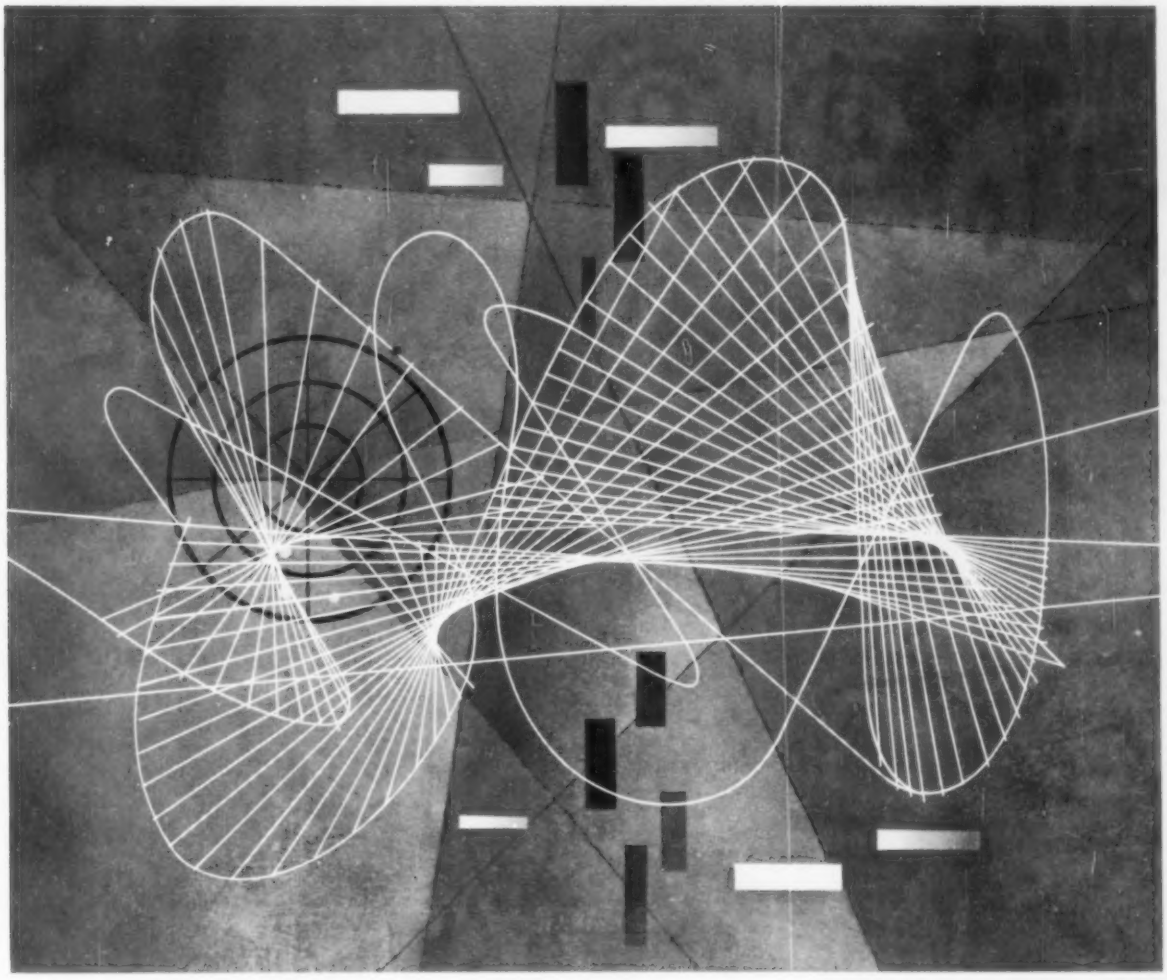
The jobs would not require full-time, year-around attendance, since these delegate Congressmen would not vote, and would have a more limited constituency than most Congressmen. Only experience could determine the working details. If it turns out that these people must spend a great deal of time in Washington, suitable research facilities might be provided to enable them to maintain contact with their scientific work while resident in the capital. In this way, working scientists could hold these jobs without losing contact with their professional work, as would occur if a scientists were to be an elected full-time Congressman for two or more years.

If the current emphasis on space research results in an appreciation of the dollars-and-cents value of science, it should be possible to get Congressional approval for the establishment of such positions. Besides the direct administrative value, the prestige this would add to science would help alleviate many of our current educational recruitment problems.

Then too, it would correct operational difficulties —inadequate salaries, poor support of long-range problems, over-centralized and bureaucratic control of basic research, etc.—under which too many scientists are struggling today.

Representing science in our government also would reflect favorably in the eyes of the rest of the world. Europeans have long criticized us for not recognizing the deeper implications of science. Such steps would indicate that the U.S. was maturing culturally. But most important, the President and Congress would benefit from full collaboration with American science in reaching and carrying out major policy decisions.

If it is desirable to have scientific representation in the upper levels of the national government, it also is desirable at state and local levels. And perhaps more of our large businesses should look around the table at their directors meetings. Those who see no scientists sitting there might be wise to consider what would happen if they were to add some "green grass" thinkers to their boards. ■



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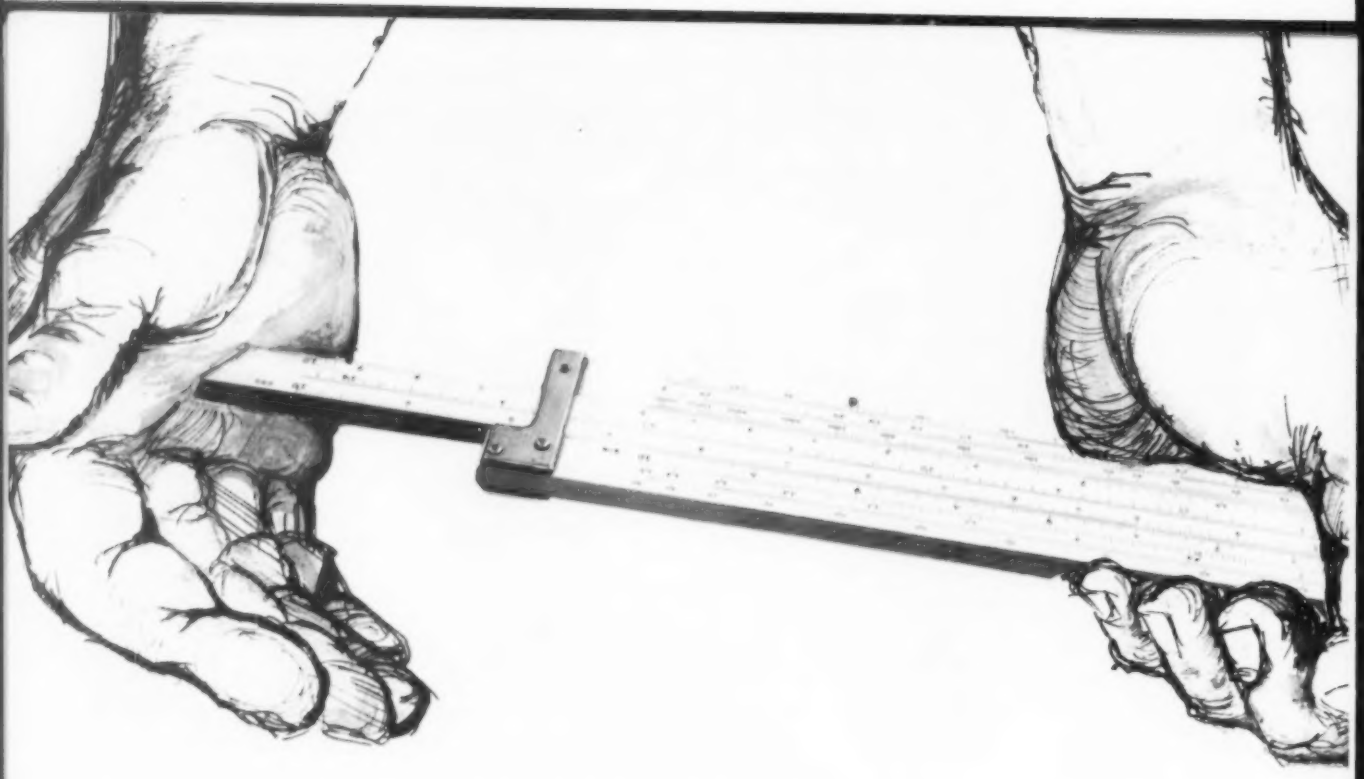


by **Earl C. Kubicek,** *director of alumni relations and placement*
Illinois Institute of Technology

Is there really a

PROBABLY THE MOST WIDESPREAD unspoken thought of experienced engineers today is, as the Red Queen said to Alice in Wonderland: "Now here, you see, it takes all the running you can do to stay in the same place. If you want to get somewhere else, you must run twice as fast." The engineer's quandary in today's economy is, "how do I run faster?"

Many engineers cannot understand why a shortage impels employers to engage in cut-throat competition for new graduates while refusing proportionately better salaries to the experienced engineers already on their payrolls. Why accept employe terminations and then pay a high price for new personnel not nearly as qualified?

One well-publicized answer—coming as it did in the midst of countless comment on the acuteness of the shortage—held that the shortage of engineers is nonexistent, a myth perpetuated by the engineering manpower experts.

This view is lead by economists Dr. David M. Blank and Dr. George J. Stigler, who first stated it in their book, *The Demand and Supply of Scientific Personnel.* Blank and Stigler are advancing the premise that if there really were a true shortage of engineering personnel in industry, engineer's salaries would rise in relation to those of other workers.

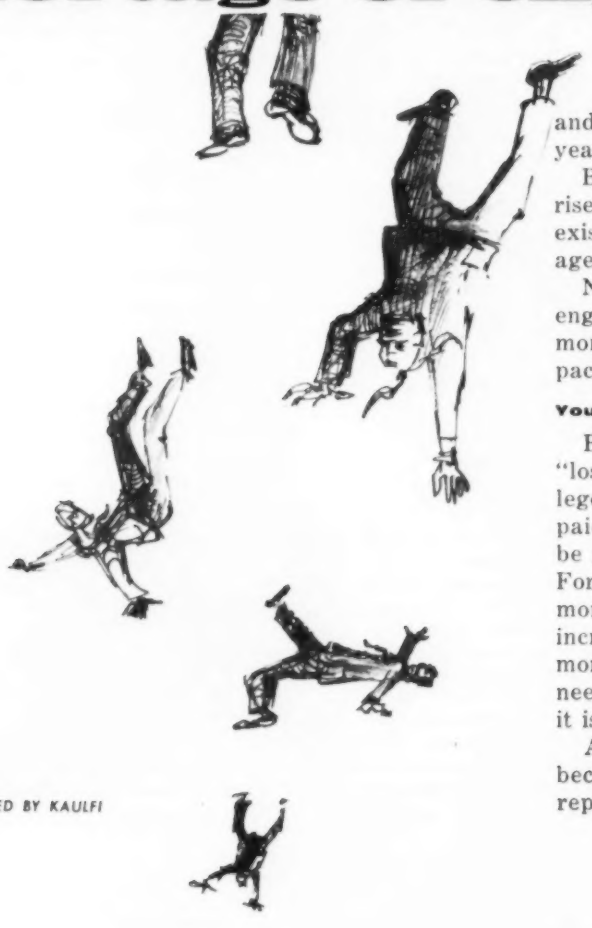
Although the demand for engineers has grown rapidly, they say, the supply has grown more rapidly. Engineering salaries have drifted downward in relation to other workers' and they have lost ground compared with doctors and college teachers. Increases in demand over supply, in a free market, will manifest themselves in a rising price market. Therefore, they conclude, there is no shortage of engineers.

Those of us in the business of supplying and hiring engineers (such as the technical manpower consulting firm, Deutsch & Shea Inc., New York) feel differently. Deutsch & Shea, taking issue with Blank and Stigler's conclusions, pointed out the rise in starting salaries in the 10-year period ending with 1957.

In 1947, the average starting salary for the graduating engineer was $244 per month. By 1950 it had risen to $260 and was just beginning to climb: 1951, $270; 1952, $305; 1953, $325; 1954, $345; 1955, $361; 1956, $394;

Everyone talks about the "shortage" of engineers, yet during the past year thousands of engineers walked the streets in search of work or were used as technicians.

shortage of engineers?



ILLUSTRATED BY KAULFI

and 1957, $433. In 1958, it was $460, and this year it is estimated at $475.

Between 1950 and 1959 this accounts for a rise of 83%—an undeniable example that there exists a real, supply-and-demand-type shortage, at least of beginning engineers.

Now it is true that the salaries of experienced engineers (probably averaging about $800 per month with 10 years experience) have not kept pace with beginners' salaries.

You can't spend percentages

But it is not quite correct to say they have "lost ground compared with doctors and college teachers." Teachers were so grossly underpaid that any increase in their salaries would be reflected in a distorted percentage increase. For instance, if a teacher were making $200 a month in 1950 and $400 in 1959, the percentage increase would be 100%. Statistically, this is more of an increase than earned by the engineer; yet in terms of actual increased dollars it is less.

As for doctors, comparisons are impossible because they are mostly self-employed. If their reported earnings have shown a greater increase

than engineers in the past decade, this could very well be attributed to today's stiffer income tax laws. There is no way of knowing how much doctors really make today or how much they really made a decade ago.

A better way of determining the extent of the shortage is the survey conducted each year by the Engineers' Joint Council. The council polls several hundred firms across the country that are representative of American industry seeking professional engineering talent. There has not been one year in this decade when the requirements were satisfied by actual hirings!

Want more money? Quit

The shortage of engineers today is not only driving salaries upward but is fostering job-changing of experienced engineers on an unprecedented scale. The simple truth of the situation is that an engineer can almost always make more money by changing jobs than he can by staying with his present employer! The reason for this is not that there is no shortage of engineers but rather that many managements even now are not yet fully aware of just how serious the shortage is.

Despite the fact that many firms have not raised the salaries of their own engineers to what they are willing to pay their competition's engineers, they do hold engineers in higher regard than other workers. Most firms that must reduce their forces make the first cuts in production workers and try to keep their engineers and scientists.

When North American Aviation lost the Navajo missile project, it laid off about 12,000 workers. Some of these were engineers, but they were "expendable" engineers and the lay-off provided a house cleaning.

This feeling is borne out by the statement from Douglas Aircraft Co. in a recent cut-back that it "laid off no graduate engineers of any great worth."

There are attempts to get along with fewer engineering and scientific personnel than once was contemplated (though industry often meets a point of diminishing returns). An official of General Electric said, "Today we wouldn't think of starting a graduate engineer in product test work, as was done before the war. We put him right in with an experienced engineer where he helps solve more stimulating problems."

Last September, the annual college recruiting survey prepared by the industrial members of the Midwest College Placement Association showed a continuing downward trend in technical requirements—and that industry was able to satisfy only 89% of its final requirements after adjustments. In 1957, the same report indicated that 66% of industrial requirements were met.

A Northwestern University survey, while based upon information supplied by industry at an early date—not upon actual case history—showed, in the 1959 report, that there would be a 13% increase in need for engineering personnel among the more than 200 firms surveyed.

Our experience in the placement division of Illinois Institute of Technology, which handles more than 500 scheduled company visits annually in search of engineers and scientists, leans more toward the Northwestern picture than the College Placement projection. Our contacts with companies indicate an upswing in the balance of 1959 in positions available totalling some 10% over 1958.

Matching man and job

Last year, in spite of the recession, there were definitely more positions than manpower, but there was a greater degree of selectivity on the part of industrial recruiters. More stress was laid on the matching of the man to the job, if at all possible. This represents a trend away—if it ever existed at all—from the stockpiling of manpower for future needs.

Hundreds of company interviews indicate to us that there will be another increase in demand in 1960 for engineers and scientists.

Carborundum, Ford, Charles Pfizer, International Nickel, Air Reduction Co., and many others have increased their needs for engineers from three to six times over the past decade. A good part of the need is for R&D engineers and scientists. A. H. Batchelder, vice-president of Standard Oil's California Research Corp. explains, "We're not moving along as well as we'd like in some fields—not because we don't get enough money, but because of the critical shortage of top-level technicians, physicists, electrical and mechanical engineers—anyone in the physical engineering field. The universities just aren't turning them out fast enough to meet the increased need."

One estimate is that there are 85 times as many jobs for scientists and technicians as there were 80 years ago, but only five times as many workers in the total labor force.

Because of this unevenness, by 1965, we will have a population 15% above 1955, but with 13% more people turning out 45% more goods. And by 1975, we can expect to see the population up 130% from 1955, with 26.5% more people turning out 110% more goods.

Engineer unions: a paradox

One of the strangest paradoxes in this rather topsy-turvy picture has been the development of "engineering unions." John E. Gagnon, director of personnel and labor relations for Olin Mathieson Chemical Corp., a

THE AUTHOR

Widely-known in engineering recruitment circles, Earl C. Kubicek is himself a registered professional engineer in Illinois and earned his degree in architectural engineering in 1933 from Armour Institute of Technology, one of the forerunners of Illinois Institute of Technology. After being associated with the Milwaukee Road for 10 years, he joined IIT in 1946. He is now director of alumni relations and placement. Kubicek is a member of the Illinois State Historical Society and has written on the engineering accomplishments of Lincoln and other historical figures as well as on college recruitment techniques and manpower training. He belongs to the American Alumni Council and was a director of that group.

Many urge that registration will thrust engineers into the same category as doctors and lawyers, who must be licensed by the state. They forget that taxi drivers and barbers are also licensed. Obviously, professionalism is not achieved via registration, but rather by functioning professionally.

few years ago said that engineers were turning more toward unions to solve their employment problems.

This observation is very much open to question, but the fact remains that steelworkers' salaries have *more than doubled* in the past decade. However, engineers with five and 10 years' experience are now making *less than double* what engineers with comparable experience were making 10 years ago.

Industry cannot deny that it was aware of the inequalities existing. Ten years ago, G. A. Price of Westinghouse Electric Co. said to the House Committee on Education and Labor: "In the early days of the Wagner Act, neither the Labor Relations Board nor, I am sorry to say, our company, gave adequate consideration to the fact that the problems and interests of professional employes are quite different from those of other salaried employes."

These were just some of the factors that sparked the movement of some engineers and scientists to band together for a solution to inequalities.

General Electric advertised five ways to help alleviate the shortage of engineering talent: guide high-school students into engineering careers; bring businessmen and educators together; help schools financially; develop employes on the job; encourage self-development.

The Engineers and Scientists of America countered with a suggestion to company executives that they examine the ratio between the company's factory wages and the salaries for their engineers with five and 10 years' experience. The ESA claimed that such a study would discourage any bright youngster from planning a career in engineering and science.

Engineer unions are, in many ways, a contradiction to the conventional union which, in the main, strives for economic gains—increased pay, union security, and fringe "benefits" as ends in themselves.

The engineer unions, while certainly concerned with the economic gains of its membership, are motivated more by the achievement of these ends as a recognition of the value of engineering and science to society. For example, the Council of Western Electric Technical Employes professes a status of "purely professional" bargaining units as opposed to the Western Electric Co. union which the council believes to be detrimental to its "purism."

The union bond is pride

The real force holding these unions together seems to be their desire to change established management practices, which, in their view, are harmful to the professional pride of engineers.

Their house publications seem mostly concerned over several features in today's management: unilateral decisions in merit increases without giving professional staffs definite information on the actual workings of the system; the stress being laid by industry on the shortage of engineers as contradictory to the policies in connection with staffs already employed; and the great disparity between salaries offered beginners and those of engineers with five, 10, or more years experience.

Then, too, rightly or wrongly, engineers feel there are "gentlemen's agreements" between companies in the same industry which prevent them from getting more money elsewhere. As a result, some engineers feel, ironically, that they have to change fields and thus use their talents in areas other than those in which they are experienced!

For a few, the union concept of unity is the best way to achieve strength. Unimaginative management easily can foster growth of that concept.

'Bad' bosses—'good' workers

Let's take the case of the young engineering college graduate. At the time of his graduation, he has at least four years of professional training behind him. He's eager to begin adult responsibilities and to prove himself professionally. He may have been recruited with the argument that company X is the "right company," and he's already on the way up.

Unfortunately, when he reports for work, his supervisor may be of an entirely different frame of mind. Faced with production responsibilities, he needs "hands," and has little time for the amenities of developing new recruits.

When management gives so little attention to the training and personal development of its professional men, can anyone wonder why professional turnover is so high?

In a recent comprehensive research study, typical engineers were shown to be strongly work-oriented, individualistic, serious-minded, and conscientious. They generally have a high level of energy which responds to pressure with increased exertion. And the Commission on Human Resources and Advanced Training has determined that in the undergraduate areas, engineering and the sciences attracted the most intelligent students.

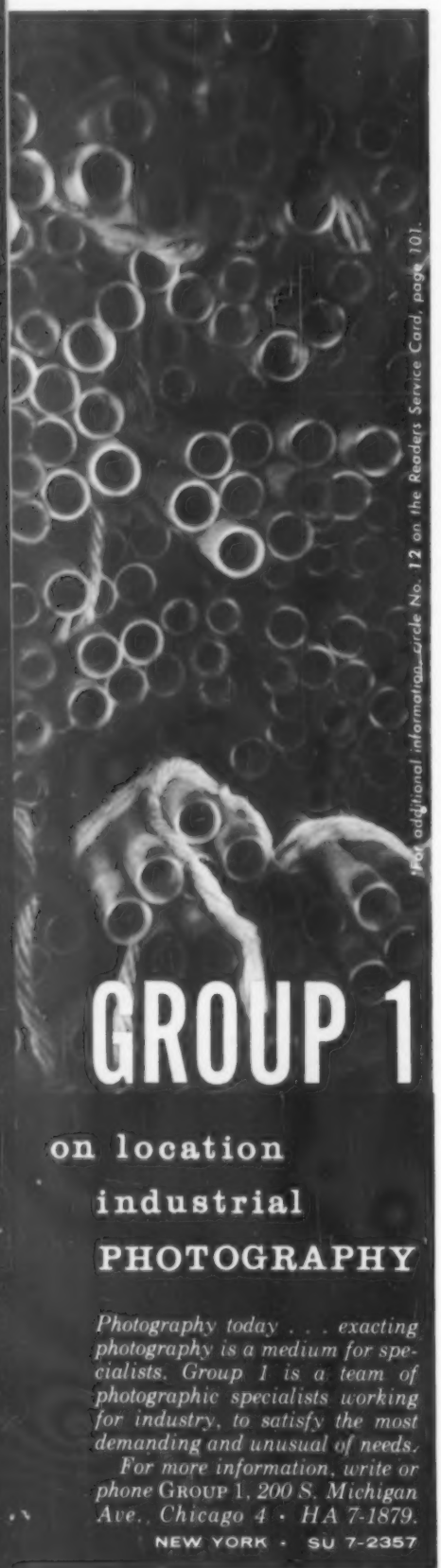
In short, these are intelligent, hard-working men. Treating them as "hired help" (as Matthew Woll, vice-president of the American Federation of Labor, views them) is a tragic waste of needed talent.

Yet, engineers are often used in non-technical positions or as non-professional technicians.

What is an engineer?

Industry's dilution of the engineering profession over a long period of time has caused the trained engineer to become confused as to the value of professional status. Industry and the public use the term "engineer" so loosely that it largely has lost its original meaning. The Professional Engineers Conference Board for Industry pointed up this fact in a recent study:

"The engineers confess that their own group lacks professional spirit and emphasis on professionalism. They lay some of the blame on com-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pany employers of engineers in not clearly defining who is, and who is not, an engineer."

The lack of this "professional spirit" forces the engineer to look with favor on the managerial route as the only route to advancement. Surveys have shown that there is no strong inclination on the part of technical personnel to stay in the technical field. There is little chance for recognition.

The grass is greener

Ironically, engineers in management feel there are ample opportunities for advancement in engineering, even though they themselves moved out of the field to achieve personal recognition and success!

The situation is made more critical by the serious decline in recent years in the number of young persons reaching the age when it might be reasonable to expect them to enter engineering and science.

According to a B. F. Goodrich study, the number of young people reaching college age—18 to 24 years—has been declining steadily for the past dozen years. The number of college students in 1959 is nearly the same as in 1936, about 16 million. Projecting these figures and known birth-rate increases, there will be about 27 million in college by 1975. But how many of these will be pursuing a career in engineering or science?

There were 16 million young people in the college age bracket in 1940. This had risen to 16.8 million by 1945, but had dropped to 16 million by 1950. The decrease continued to 15 million in 1955. Increases now will bring the figure back to 16 million in 1960; 20 million in 1965, 24.7 million in 1970, and 26.8 million in 1975.

However, there are no assurances that there will be any reasonable increase in the number of engineering and scientific personnel beyond the 18.6% now being graduated annually.

The high level of earned degrees at the bachelor of science level was reached in 1950, with slightly more than 50,000 degrees in engineering awarded. This figure has dropped steadily ever since.

If we take the current ratio of 186 engineering graduates for every 1,000 awarded BS degrees, we will have accumulated a deficit of 100,000 engineering and science graduates by 1967.

This year, and next . . .

Something near 59,100 bachelor of science degrees will be awarded in 1959 and five years from now an estimated 76,400. Will this be enough to take care of normal attrition, as well as the increasing demands of a modern technological civilization?

Probably not. One effect will be to increase starting salaries of engineers even more. The rise will continue this year to an overall average of about $475 for engineering graduates just out of college. Next year it may well hit $500.

As in the past, the levels of various types of engineering—electrical, mechanical, chemical, etc.—will vary with economic demands. At present, electrical engineers are leading, demand-wise, and probably will continue to do so. Not only national defense needs but also the myriad industrial applications of electronics will be contributing factors. Physicists and mathematicians also will continue in demand.

While industry searches the campuses for qualified candidates for employment, the colleges seek candidates for professional degrees to fill up the ever-widening numerical gap between beginning and graduating engineering classes.

. . . and then what?

Birthrate figures, like the mirage on the desert, can stimulate false thinking. Professional education is not easily attainable. The rewards seem pitifully few to those who actually are engaged in it. The faint of spirit leave early. The hardy stay on but move into other fields in order to attain some degree of success, either financial or personal recognition.

Scientific and engineering achievements can be obtained only by those professionally trained. They cannot be attained by unionism which comes about only through the lack of recognition of personal attributes by management.

A shortage of engineering and scientific personnel has existed for some years, and there is little reason to believe that it will cease in the foreseeable future.

But, the picture is not so dismal that there is no hope. Increased efficiency in personnel usage can alleviate some of the difficulties. A more enlightened management will encourage more engineers to stay in their fields—and advance in them. ■

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We would be modest indeed if we failed to hint that much of the rapid expansion—first in research and then in actual industrial use of the rare earths—has been at our gentle urging.

The facts speak for themselves. Rare earths have come of age. They are important production materials in a broad cross-section of American industry.

So if you are thinking *new* . . . new ideas, new processes, new materials, new products . . . look at the rare earths.

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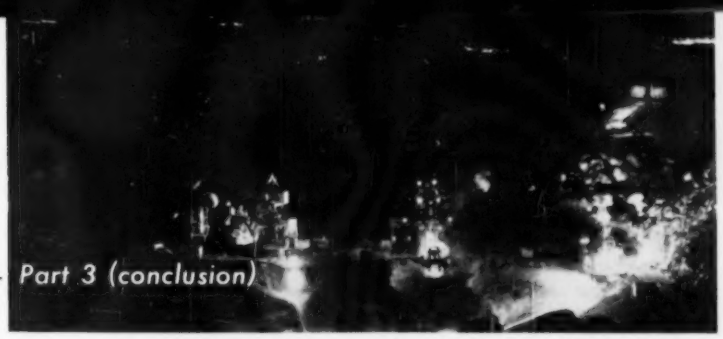
TOMOR

Consolidated Electrodynamics illus.

"First we throw something into space, then a little more, then a shipload of instruments ...then ourselves." —Fritz Zwicky

The Flying Machine: a New Era— Part 3 (conclusion)



1700-ACRE *rocket research center is owned by Rocketdyne.*

ROW'S SPACECRAFT

by **K. M. Wylie Jr.,** *I·R contributing editor*

TURBOJETS, ramjets, and rockets are being installed in more and more airframes, but propellers are going to be pulling aircraft for many years to come. Why? The answer is a familiar one: lower cost.

It would take about seven dollars a minute to keep a turbojet transport circling above an airport waiting to land in periods of heavy traffic or bad weather, according to D. J. Lambert, Vickers Armstrong Aircraft Ltd., Weybridge, England. The cost for a turboprop would be only four dollars. And it wouldn't take much of this circling to cancel the faster pure jet's point-to-point time advantage over the turboprop.

What's more, Lambert points out that only 25% of all air passengers ride more than 1,000 miles on each flight, the range in which the turbojets have their economic advantages. About 50% travel less than 500 miles, the range in which the turboprops are supreme.

Men at the dials

In the matter of manned flight, certainly men will continue preeminent at the dials and switches of flying craft. But no technological bigotry of pilots, designers, or a flying public will be allowed to create closed covenants against worthy instrumented control systems. Economic and social, not to mention military, necessity would never allow it.

Today the USAF is known to favor combined manned and unmanned space and air weapons as the best deterrent force. This attitude was reflected, for example, by SAC commander-in-chief Gen. Thomas S. Power. "Missiles [in the future] will probably be integrated into the competition," he said. "There will be ways of judging readiness, of measuring preparation from alert up to the time of firing."

This confluence of missiles and aircraft, racing toward the same goal, can be seen in the two foremost heavy air weapons flying U.S. colors today, the *B-52 Stratofortress* and *B-58 Hustler.*

Updated and now called the *B-52G,* the *Stratofortress* has been converted to both a bomber and a missile-launching platform. It is designed to carry two *GAM-77 Hound Dogs*—winged, 40-foot, Mach-1.6 air-to-surface weapons, which can mount all kinds of warheads including nuclear ones. The biggest is the 20-megaton bracket.

With a range of about 350 miles, a *Hound Dog* can be **a.** launched toward heavily defended targets from a distance, protecting the mother ship from direct, retaliatory attack, **b.** launched to seek out two separate targets or, **c.** in a modified version, launched as an e.c.m. (electronic-countermeasure) vehicle. In the latter case, it would help its mother-ship avoid detection and destruction during missions by providing it with a friendly electronic environment.

The *Hustler,* also missile bearing, has been described as the ideal combination of an aircraft's reliability, man's judgment, and a missile's speed and readiness.

As in any complex endeavor, be it love-making or parapsychology, the means to success in space flights and investigation is research: well-founded, both intensive, and constant. Concerning space, to be sure, there are differences of opinion about what this research should cover.

There are those who hold that the genuinely advanced space scientists long since have gone beyond studies of spaceship design, equipment, and flight problems. These researchers, it is said, now are working on problems of sustaining life on the other planets and altering planetary orbits to improve future living conditions.

Getting to the planets

Essential though all this may become, the fact remains that the initial work, on how to get to the planets, is just beginning—fundamental investigations, studies, and developmental research. And it has been pointed out that space travel can become a reality only if scientific and technological progress in every field is made and applied to it.

According to the National Aeronautics and Space Administration (NASA) the United States is to launch at least one satellite or one space probe rocket each month for the duration of the decade.

As of this writing, the Senate had approved space-exploration expenditures of $485.3 million, about $4.75 million more (for a high-energy solid and liquid propellant research center) than authorized by the House.

One of the great reasons for this, of course, is to equal, then surpass, the Soviet Union in all phases of astronautics — including the landing of a man on the moon. Sen. E. Stuart Symington (D., Mo.) has estimated the U.S. situation *vis-a-vis* Russia would not be hopeless until about five years from now at the present rate of development. The Russians' big lead now appears to be in the sheer brute force of their bigger rocket engines. They can put more in space than we can. In this connection NASA director, Keith Glennan, who at one point earlier this year had said we were 18 months behind the Soviets in space programs, has outlined this program:

1. *By 1960*—an Atlas second stage to rocket 6,000 lbs. into orbit around the earth or 1,000 lbs. to the moon.

2. *By 1962*—a cluster of rocket motors producing 1.5 million lbs. to send 20,000 lbs. around the earth or take 4,000 lbs. to the moon.

3. *By 1964*—a single 1.5-million-pound thrust rocket engine.

4. *By 1966*—a cluster of four 1.5-million-pound rockets to hurtle 150,000 lbs. into terrestrial orbit.

The moon by 1965

A roughly concurrent report issued by the U.S. House of Representatives Select Committee on Aeronautics and Space Exploration (and prepared by an international group of scientists, engineers, industrialists, and military and government leaders) predicts that man will orbit the earth by the end of 1959; land on the moon by 1965; be on Mars and Venus three years later; and travel almost as fast as light, that is, 670 million mph, within 40 years.

On the subject of putting a man on the moon, Dr. Homer E. Newell, NASA's assistant director for space sciences, says we could do it in two years if we 1. develop a successful capsule to house him; 2. provide him with foolproof safety and escape mechanisms; and 3. send up a long series of animal test flights to pave the way.

Reaching such goals will require across-the-board advances in many fields including metallurgy, mechanics, thermodynamics, physical chemistry, electronics, aerodynamics, fuels, lubricants, cooling agents, ignition components, and anti-radiation-materials.

Heat is one of the biggest problems in space research, heat of engine combustion and heat of the rocket body caused by friction with the atmosphere and even with particles in space. Not only meteoric dust but also other particles in the rarefied gas which satellite studies have shown exists in the imperfect vacuum of space.

Solving the heat problem can be done in some areas by using outright heat-resistant materials. Some of the newer metals are in this category, such as beryllium, titanium, vanadium, chromium, niobium, molybdenum, tantalum, and tungsten (*see* THE WORLD'S HOTTEST ALLOYS *in this issue*).

Paper made of scrap mica at Bendix Aviation Corp. has proved an excellent insulator in high-temperature capacitors. Research at Washington State (College) Institute of Technology, made relative to Boeing's *Dyna Soar* project, is investigating the lubrication of bearings heated as high as 1,800° F by high-speed flight.

Since petroleum and organic-silicone lubricants quickly evaporate and oxidize at such high temperatures, Washington State's researchers are looking into high-melting-point solid-film inorganic lubricants. E. N. Klemgard, head of the

SATELLITE STATION *3,000 miles above western North America is approached by a nuclear rocket in this artist's conception painted under Aerojet-General direction. At right, North American's X-15, already a spaceship reality, rides under the wing of a B-52.*

chemical engineering section, says his lab has developed a new process by which chlorine and fluorine compounds are diffused into grain boundaries of new nickel alloys used in spaceship bearings.

The first part of any vehicle to plow through the oxidizing atmosphere on its way to space takes a greater punishment than any of the other parts. This obvious fact is the reason why a prime area of space research centers about the nose cone. Heat and friction would destroy rocket nose cones save for protective measures to the contrary.

Cooling nose cones

But aside from the bulldog approach of heat-impervious materials, there are other means of getting the rocket's fore profile to the destination intact. One is the sweating method, in which the cone is made porous and cooled by forcing compressed gas through its surface.

Another is the ablation process, in which the cone—made of asbestos, ceramics, fiber-glass, nylon, or powdered-metallic compositions—sluffs away ordinary ruinous heat by melting, burning, or sublimating, that is, turning to a gas at the nose surface.

A third method is the heat-sink method in which a plate or slab of a material such as byrillum or graphite—placed as a bulkhead between the outer nose and the rocket's payload—soaks up the damaging heat and retains it temporarily.

There is also the more subtle magnetohydrodynamic method, in which air particles are fended off from the nose cone by the magnetic field along its surface. These particles already would carry an electrical charge at the altitudes and speeds of rocket flights.

This same force, incidentally, also would be a means of applying braking force to an incoming rocket. As a vehicle enters the denser atmosphere, the air is compressed and heated until it partly ionizes. Generating such a strong magnetic field at the rocket-body surface would cause an interacting magnetic drag force, slowing the vehicle.

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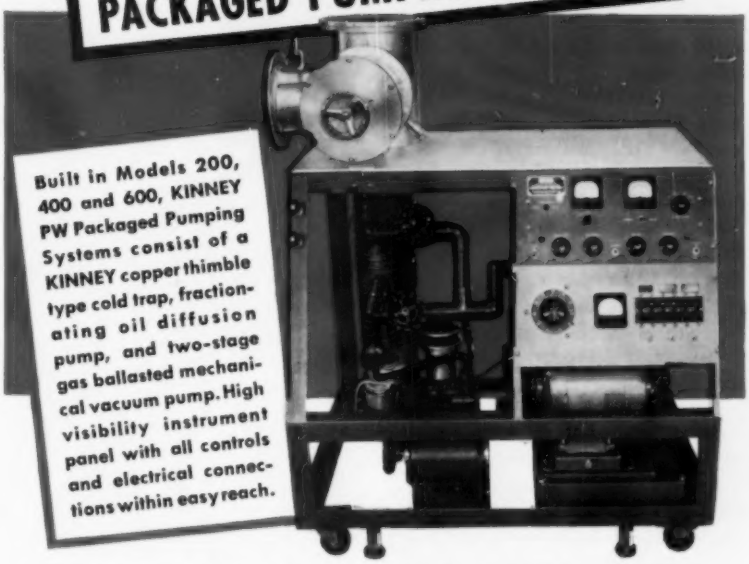

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periments in the Fourth Century and continuing through the Chinese black-powder rockets, the fuels and engines used in rocketry have progressed until today scientists are researching methods for driving space sailing ships before the "winds" of sun rays.

Solid vs. liquid fuel

Be this as it may, chemically fueled engines are the rocket propulsive power of the near future. Both liquids and solids have their advantages. Liquids can be controlled and throttled more easily, have very high thrust levels, and can be used for auxiliary power aboard the rocket. At the same time, their rockets are extremely complex; instant readiness is more difficult to achieve; and they are dangerous to handle.

Solid fuels are ready instantly, more reliable, and their rockets can be built relatively economically. Yet they are difficult or impossible to control and throttle; they do not burn as long and do not allow for auxiliary-power takeoffs.

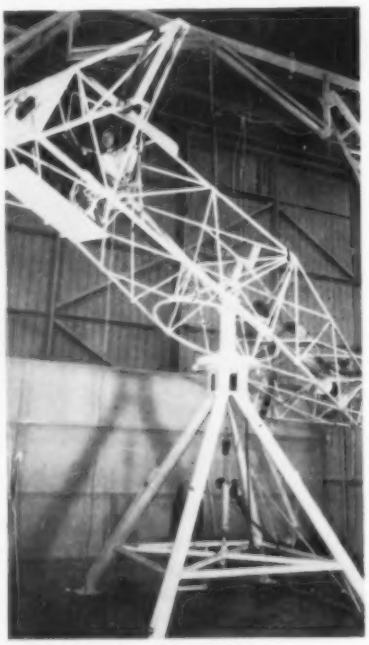
Packaged liquid fuels are a gambit by the liquid advocates to make their fuels as quickly ready for firing as the solids, and the solid makers are working to stretch the burning time of their fuels.

Non-chemical rockets include both thermal and non-thermal power plants. In the first group are engines used for lifting high payloads beyond the earth's or other planets' gravity fields. The nuclear fission rocket is this type and some models such as the *Kiwi-A* (named for the non-flying New Zealand bird) are under development. The Kiwi-A is to be ground-tested soon.

Other possible thermal plants are the thermo-nuclear rocket, the gas-phase nuclear fission rocket, the electric-discharge heating rocket, and electro-magnetic induction heating model. Propulsive power in the nuclear-fission rocket, for example, comes from heating a propulsive fluid such as liquid hydrogen in the reactor, then spewing it out in gaseous form through a nozzle for thrust force.

The non-thermal rockets are low-thrust powerplants which use electrical and magnetic forces for acceleration. In this group is the plasma engine, in which a gas is heated to a high enough temperature that it conducts electricity, then injected into an electrical field where it exerts the same forces as an electric-motor armature.

Another type, the ion engine, heats a metal such as cesium until it reaches ionization temperature. At this temperature it is a positively charged gaseous mass of cesium molecules which can be accelerated by an electrical field and discharged at high velocity for propelling thrust. Particles that conceivably might be ejected by electrical fields for propulsion include electrons, protons, neutrons, alpha particles, nitrogen ions, and last but certainly not least, photons. Photon propulsion, which is possible theoretically, is not likely to be feasible for some time. If it does come, it could transport us to a theoretical top speed of 95% of the speed of light, or about 177,000 mps.



'FEELING OF SPACE' *is gained in this Boeing reaction-control simulator. The device is thrust slowly into various positions by blasts of compressed gas.*

Two leading U.S. space scientists believe flight at light speed will remain an elusive goal. According to Dr. James A. Van Allen, of the State University of Iowa, and Dr. Newell, at only 3/10th light speed, or 56,000 mph, each square centimeter of a space ship's nose would be bombarded by a billion protons a second plus as many electrons.

At such speed, they say, this bombardment would be equal to a radiation level of about 20 million roentgens an hour (1,000 an hour is considered lethal). While shielding might lower the radiation hazard, erosion of a ship's outer surface by contact with interstellar hydrogen atoms would damage a vehicle's physical structure.

Present plans for plunging into space, while not as exotic, are far more advanced than anything planned definitely even last year.

First hypersonic flight

Flight testing has begun on the latest model *X-15* (three models have been built). This 50-foot-long rocketship, the direct descendant of a series of rocket craft beginning in 1944 with the Bell *X-1* and Douglas *D-558-1*, will be the first manned vehicle to fly at hypersonic, that is, Mach-5-plus, speeds.

As of this writing, the *X-15* has made four captive flights, slung beneath the wing of a B-52, as well as one free-winging, non-powered flight to test its stability and control. The three *X-15s* will run a series of high-speed and high-altitude tests over the Air Force-NASA High range, flying from Wendover, Utah to Edwards Air Force Base.

The first 50,000-pound thrust rocket engine for the *X-15* is expected to be installed in the second of the black research rocket planes in August. Next December or January the ship should fly, for the first time, in a series of low-powered tests.

The high-speed mission, run over a 495-mile course, may take the slim, wedge-tailed rocketship to speeds of 4,600 mph. The altitude runs will consist of high-arching ascents to the 100-mile level, followed by a steep dive back into the dense air to test re-entry characteristics and reactions.

What science learns from the *X-15* it expects to pass on to the betterment of an even more advanced project, *Dyna-Soar*. The name, contracted from dynamic soaring, refers to the operations of this futuristic project, scheduled to be aloft in the 1960s.

This spaceship is to be an orbital, hypersonic glide bomber, a

manned rocket vehicle which will glide orbitally about the globe, dipping in and out of the atmosphere and reaching speeds of 17- to 18,000 mph. Its goals will be reconnaissance, strategic bombing, and explorations of "near" space.

As planned, the glide bomber will weigh less than 25,000 lbs., blast aloft on the thrust of three rocket stages of at least one million pounds (first stage), 250,000 lbs. (second stage) and 25,000 to 30,000 lbs. (third stage). Both Boeing Airplane Co. and Martin Co. are competing for the final *Dyna-Soar* contract, to be awarded at mid-year.

Martin, which is prepared to undertake the project as prime subcontractor if awarded the contract, has readied a team including Minneapolis-Honeywell, Goodyear Aircraft Corp., Bell Aircraft Corp., American Machine Foundry, and Bendix Aviation Corp.

By the time you read this, a 325-lb. satellite will have been sent into elliptical orbit by an *Able 3rd* rocket. Purpose: to gather data on the intense radiation belt and magnetic flux.

Commencement

This is only the beginning. In the near future a series of rockets will thrust into space to carry forward the future stiff schedule of U.S. space exploration:

August (no firm date yet): A satellite patterned after the USAF *Explorer* will be sent into orbit around the moon.

1961-62 (possibly 1960 for the U.S.S.R.): A 2,000-lb. conical capsule, carrying a man, will be put into 24-hour terrestrial orbit 100 to 150 miles above the earth, probably as an *Atlas ICBM*.

If anyone had prophesied anything as definite as this even five years ago, he would have been laughed at. Today's spacecraft make the timetable plausible, even conservative. And after that? "After-that," in this business, is a revolutionary concept—one that may constitute yet another new era for the flying machine. ■

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Circle No. 16, page 101.

continued from page 84

Tomorrow's light

Electron tubes and transistors, of course, also can serve as non-mechanical switches, but they do not possess electrical isolation.

By providing more than one electroluminescent or photoconductive element, solid-state analogs of multi-pole and multi-coil relays may be made. An interesting feature of such switches is that the electroluminescent element provides a visual indication of whether the device is "off" or "on." While this feature is possessed by mechanical relays, it is not by vacuum tubes or transistors.

If optical feedback of light from the electroluminescent element to the photoconductor is allowed in these photoconductive - electroluminescent (PCEL) devices, then a useful storage, or "lock-in," action is obtained. Since both photoconductive and electroluminescent matrices may be prepared with a hundred or more elements per square inch and at a low cost compared to magnetic storage elements, it is expected that they should find ready application in electronic computers.

Control elements

PCEL devices also can perform all the common logic operations ("and," "or," "nor," etc.) and hence should find wide use in electronic control systems. Such devices also can serve as power amplifiers, with many of the properties of the more familiar magnetic amplifiers. At the current stage of development, all of these PCEL devices are limited to operation at relatively low frequency because of the slow response of available photoconductors. But development of materials with faster response probably will remove this limitation soon.

For computer and control applications, it is not necessary that the electroluminescent material emit in the visible region of the spectrum; the ultraviolet and infrared regions are equally useful, and this may help in the search for better photoconductors. One experimental device, consisting of a large number of electroluminescent and photoconductive elements, may open up an entirely new field of solid-state radiation amplifiers and converters — notably fluoroscopes for industrial and medical use.

The electrical impedence of photoconductive elements is determined by the amount of radiation (visible, ultraviolet, x-ray, etc.) falling on them. Each photoconductive element determines the voltage appearing across one of the electroluminescent elements and, therefore, the light output of that element. If the incident radiation comprises an image, then this image will be reproduced in the output radiation, but at a higher brightness level or at different wavelengths than the original. With optical input, brightness gains of 100 to 1,000 already have been obtained.

Storage or memory also may be incorporated by means of optical feedback. Of particular interest is the use of such devices not only to increase the brightness of x-ray fluoroscopic images, but to reduce the amount of radiation received by a patient in medical examinations.

'Thermoelectric-luminescence'

Another field of solid-state R&D now being extensively explored is thermoelectric solid-state electric power generators and their converse, thermoelectric heating and cooling elements. A single unit can provide either heating or cooling and may be combined mechanically with an electroluminescent lamp to form a single device which will provide illumination and heating, or cooling, as needed. Such thermoelectric-luminescent panels may play an important role in the all-electric home of the future.

All of these present and potential applications of electroluminescence have emerged from Destriau's laboratory curiosity of 23 years ago. Twenty-three years hence, the world may wonder how it did without EL, just as it wonders now at life under kerosene lamps. ■

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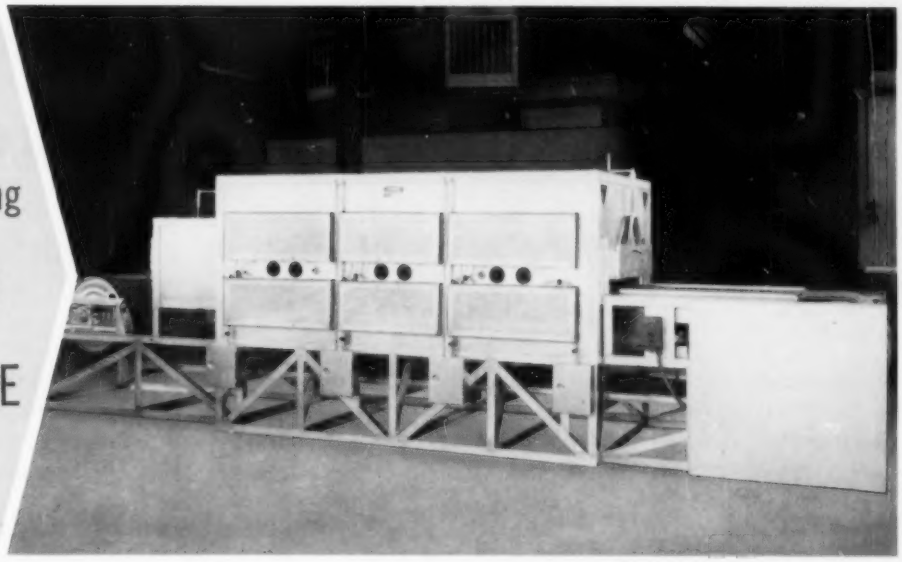

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MILITARY R&D

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3rd quarter, 1959

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A new aid in photo interpretation—"photoscat"—has been developed by Columbia Broadcasting System Labs. Jet aircraft flying at 35,000 ft or higher can take photographs and transmit them to ground stations 500 miles away.

The photograph is transmitted by tropospheric scatter propagation, and blow-ups are almost completely free of "snow" and fuzziness. Pictures of aircraft on a runway taken from a 35,000-ft altitude are so clear that identification of markings is easy.

The idea of a roll-over bar for jeeps is being pushed by a Washington manufacturer. The bar is devised to protect passengers in roll-over accidents or to turn jeep sideways intentionally as a protective cover in case of unexpected strafing or ground fire. The Army is said to be interested.

An ionic homing device that seeks all engine and furnace exhaust is being developed. The exhaust contamination ionizes the air and a sensitive artificial "nose" sniffs out and follows it as the intensity increases.

This principle is used in some of the newest missiles now on drawing boards and in test. Sniffer gear in missiles generally is not used alone, but, like mines, is combined with homing methods—sniffer, infrared, radar beams—all in the same package. Sniffer gear is extremely effective in homing on ships, industrial areas, and snorkling submarines.

Several new products which had their beginnings under military contract are:

A high-speed facsimile communications system has been installed in the New York Savings Bank. The system was developed originally by Alden Products, Brockton, Mass., for the Navy.

A paper-lined plastic foam house soon will be sold by Corporate Research Inc, Ann Arbor, Mich, to beach-house and play-house markets. The house grew out of an Army contract for portable huts to quarter troops.

Research on people: the Soviet technique

A story from Stockholm tells how Russians are training more than 1,000 top students for espionage work in America. The training center in the Ukraine is an exact copy of a small American town. The students in the "spy center" of Winniza, Russia live like average American students.

They eat in snack bars and restaurants similar to those in New York, Urbana or Evanston. Only typical American dishes are listed on the menus. Movie theaters in Winniza are like any small town theater in the U.S. and show only Hollywood films. Stores sell only American goods; the students drive Fords and Chevrolets by U.S. traffic laws. From American newspapers and books they read about the latest American sports news, movie personalities, new records, and U.S. politics.

The Swedish report says the first stage of the years-long training is devoted to a study of various American dialects, which students must be able to speak perfectly.

Another report from an official source confirms the Swedish story and brings out that other towns in Russia are reproductions of typical cities in many countries.

Few Americans speak Russian, but the study of English is required in all Soviet schools. Not only do Russians speak our language, they study our customs, habits, and even our thought processes.

When the new Soviet ambassador to the United States was delivered to Washington, we had a chance to inspect a shiny new, well-engineered TU-104A Soviet jet. More interesting than the jet, however, was its crew.

In the air terminal bar I asked the crew in my best halting Russian if anyone spoke English. A handsome young man said he was the spokesman, yet his English bore no trace of an accent. He could have come from Des Moines or Milwaukee.

He said this was his first trip to the United States. In tweed sportcoat, knit tie, and flannel slacks, he looked like an American college boy.

"Can I ask you some questions about the TU-104A?" I said.
"Shoot."
"Can it maintain altitude on one engine?"
"Fully loaded?"
"Yes."
"No."

I questioned him further about the aircraft, cruising altitude, take-off, and landing roll (it had blown a tire in trying to land short —actually it lands quite hot and carries a drag chute for short fields). He answered my questions whenever he could.

When I asked where he had learned American mannerisms so thoroughly, he answered snidely, "We have schools."

How do we differ from the Russians? They seem to take infinite pains to know more about us and other people of the world. They aren't ahead only in Sputniks.

Sincerely,

Murray Dann-Smith

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Commercial (depleted) Uranium—the uranium isotopes remaining after the removal of U-235 (with *radiation exposure about equal to that obtained in watching your TV set*)—possesses many inherent qualities of interest to many industries.

Uranium has many interesting properties.

For example, Davison Uranium has exceptional density —*68% greater than lead* and about equal to gold. This indicates usages in the aircraft, shipbuilding, tool making industries—wherever high weight and low volume are factors. It alloys readily with many metals including aluminum, chromium, copper, iron, manganese, molybdenum, niobium, nickel, silicon and zirconium. Corrosion resistance is increased when uranium is alloyed with one of these metals. Davison Uranium possesses high tensile strength and low thermal expansion. While extremely hard (Brinnell 240) at room temperature, uranium becomes very malleable as temperature rises. At 1100° F its hardness drops to about 20.

Is Davison Uranium easy to fabricate?

Davison Uranium may be melted and cast into any desired shape. It may be formed by extrusion, drawing, rolling, swaging, pressing or forging.

You can machine Commercial Uranium with conventional machine tools, bearing in mind that it has work-hardening characteristics similar to those of stainless steel.

It is necessary to machine uranium under water soluble lubricants. Commercial Uranium has been machined on a number of tools including lathes and automatic screw machines, saws, high-speed mills and centerless and surface grinders.

How about welding?

Success in welding Davison Uranium has been achieved using the Heliarc and shielded arc-consumable electrode process. At this date experiments continue in joining uranium to uranium by brazing or soldering.

How has Commercial Uranium been used?

Present applications include shielding materials, tela-therapeutic heads, isotope containers; as counterweights and static balancers. And, for many years, as coloring agents and glazes.

Is Davison Uranium safe?

Radiation exposure is virtually non-existent. AEC tests indicate that a *week's exposure* to depleted Uranium is only about *1/10th to 1/100th* the radiation received from an *ordinary chest X-ray*.

However, just as other heavy metals such as lead are toxic if breathed, care must be exercised to avoid inhalation of uranium dusts. A properly ventilated work area removes this dusting problem.

Must special storage precautions be taken?

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Is Commercial Uranium expensive?

Not at all. For example, in lots of 1400 pounds or more Commercial Uranium is priced at just $4.60 per pound —considerably cheaper than other heavy metals, with the advantage of superior density.

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IR BOOKS OF THE QUARTER

Top Management and Research, by Philip R. Marvin (Research Press Inc., Dayton, Ohio, 1953, $5.) This book, now in its second printing, was probably sent to editors at this late date with the hope that it could be revived for a third.

Stated purpose of the book is to provide executives with guidance in directing research activities within their organizations. Research can be directed in accordance with the objectives of the company, as can finance, production, and distribution functions. The author also states quite correctly that invention is an unpredictable byproduct of research which can be stimulated and facilitated by a suitably managed research program. However, invention is a sporadic and unpredictable occurrence which cannot be directed, but only provided with a fertile atmosphere to enhance the probability that it will occur.

The book discusses the research picture today, the history of its growth, the responsibilities of management, criteria for evaluating research programs, and the use of outside contracting. Material presented is compiled largely from a survey, but it has been poorly edited and weakly supplemented with ideas that might have made such a book interesting and valuable. Yet, some may find the statements of mostly unidentified industrialists interesting. These present opinions and case histories, some of value, many similar to the following little gem:

"The attitude of top management, I believe, has a great deal to do with the success or value obtained from a research program. We are very fortunate to have that understanding and attitude, and I believe, as a result, have been able to more than justify our research accomplishment."

The book also gives limited data and superficial discussion on miscellaneous subjects of interest—financial returns from research (mostly estimates of future expectations); research expenditures in the chemical industry in 1950 (2.7%); how much to spend on research (1% to 10% of sales); minimum effort for yearly research done within the firm ($100,000) or carried out under outside contract ($10,000); and the need to recognize a product resulting from research and produce it.

The author is in favor of research. ■

The Scientific Revolution, Challenge and Promise, Edited by Gerald W. Elbers and Paul Duncan. (Public Affairs Press, Washington, D.C., 1959, $6). This book is the result of a 1958 Yale University symposium on "America's Human Re-

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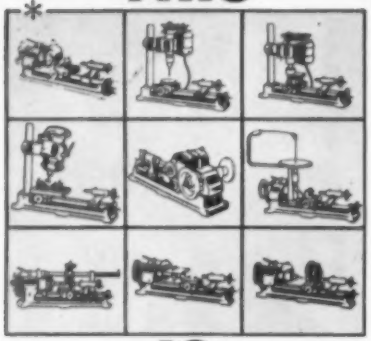

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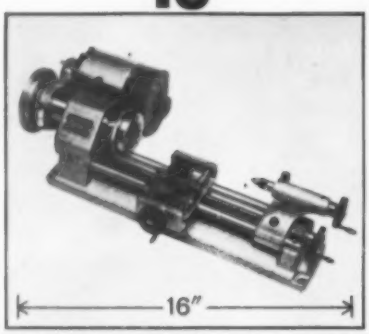

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The symposium was held to assess the status and rate of advancement of American science relative to that of the Soviet Union after the launching of the first satellites. Once again it is emphasized that scientific advance is reckoned from the final result rather than from the preceding discoveries which made the result possible.

The papers in the first part of the book, authored principally by scientists and administrators, are grouped under the headings: "America in an age of science," "the Soviet challenge," "developing an adequate science program," and "public understanding of the scientist." Despite the fact that such a collection by many authors necessarily lacks cohesion and opportunity for depth, an excellent appraisal of the status and problems of American science is presented, including the interrelated roles of science, engineering, industry, education, government, and the public.

The resulting outlook is bleak. Research efforts have grown tremendously in recent years to an investment of $12 billion yearly in basic and applied research. Of this, the government conducts or pays for three-quarters, mostly in applied R&D for the military.

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(continued on page 104)

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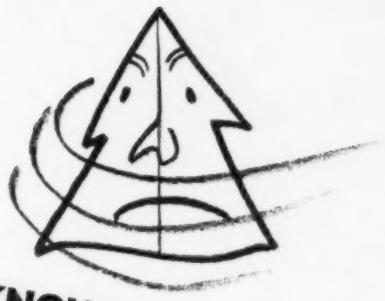

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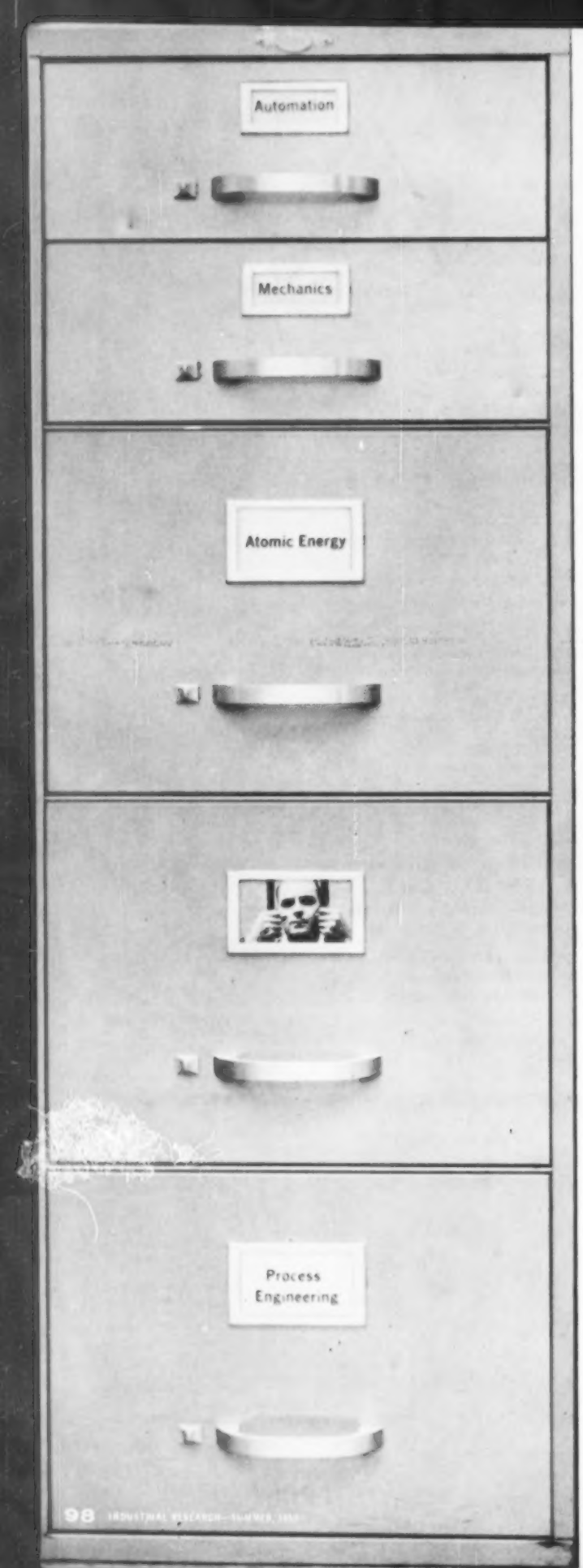

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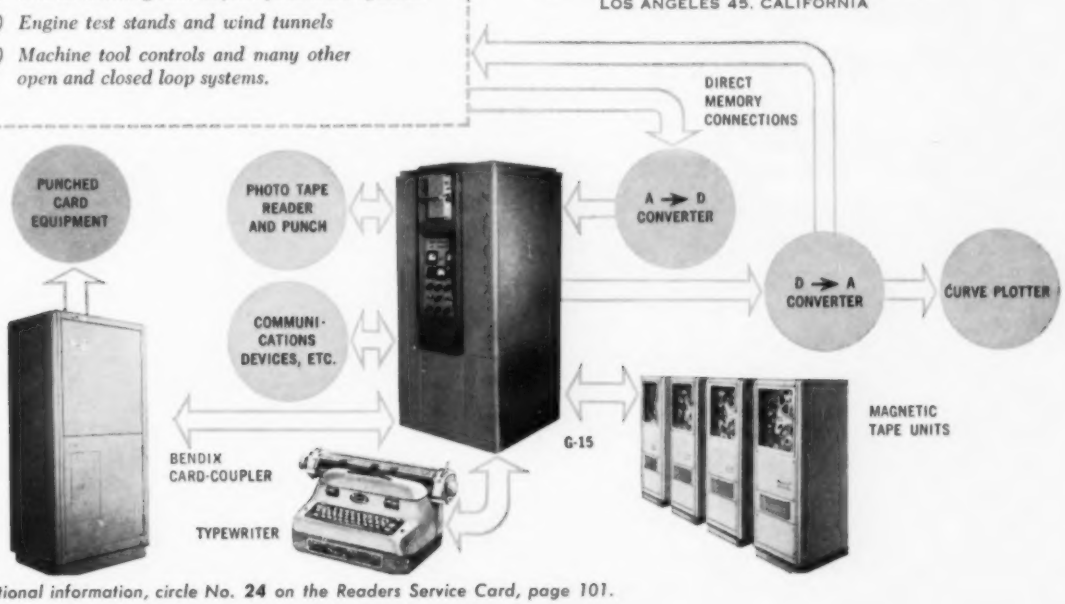

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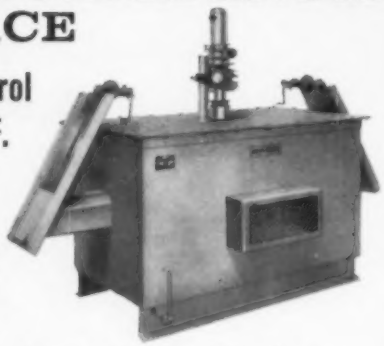

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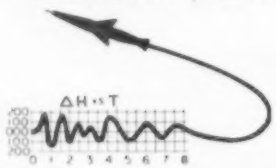

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the costly time lapse between the start of a project and progress, and the ability to exploit a discovery.

Basic research *(see special section, page 43, this issue)* only can be justified by big companies, and even here it is carried out in part to attract and retain outstanding scientists who are needed to assist with development programs.

The picture of education in universities and high schools is extremely discouraging. It becomes increasingly difficult to attract high-calibre teachers and to replace retiring instructors. Government, scientific, and engineering activities, which represent much of the nucleus and management of the nation's scientific efforts, continue to lose staff members to industry and often are unable to get replacements of equal ability.

To add to the desolate picture, the public remains largely uninformed about scientific needs, and is reluctant to provide increased support to education—the startling effects of the first Soviet satellite launchings now having worn off.

One of the most pressing needs for accelerating American scientific progress is an assessment by the federal government of what constitutes an adequate science program. One author, John T. Connor, president of Merck & Co. Inc., feels that none of the existing government agencies has examined the overall problem:

"Federal responsibility for basic research in this country inevitably must go beyond initiating industry programs. I would say that the first priority for the federal government is to make an assessment of just what constitutes an adequate science program and to evaluate the contributions to R&D being made by government, industry, and the universities. This assessment and evaluation would provide the essential basis for a comprehensive national science program."

The second part of the book, dealing with "forty million growing minds," "the coming crises on campus," and "the education and the use of superior talent" is disappointing in view of the book's theme and, perhaps significantly, consists primarily of articles by educators. Most of this section deals with the mechanics of university financing and operation. Two authors consider the important goal in education to be the doctor's degree, implying it is the point of transition to creative ability.

One might be reminded of a statement attributed to Einstein to the effect that the job of satisfying formal requirements for his doctorate left him too exhausted to perform any creative work for a year. ■

—Harold L. Garbarino
technical editor

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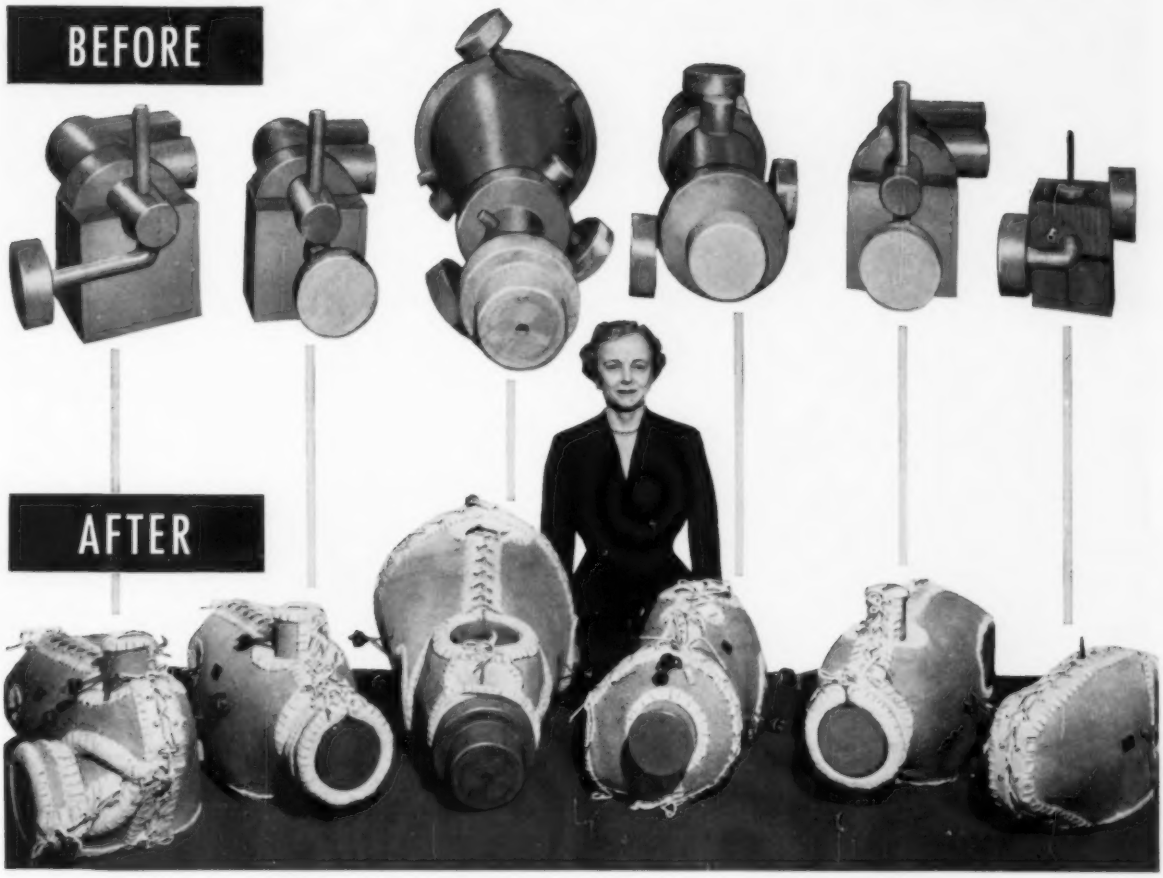

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A more complete technical description of these new lithium dispersions is just off press. This literature and samples are available upon letterhead request to Technical Literature Department, Foote Mineral Company, 480 Eighteen West Chelten Building, Philadelphia 44, Pennsylvania.

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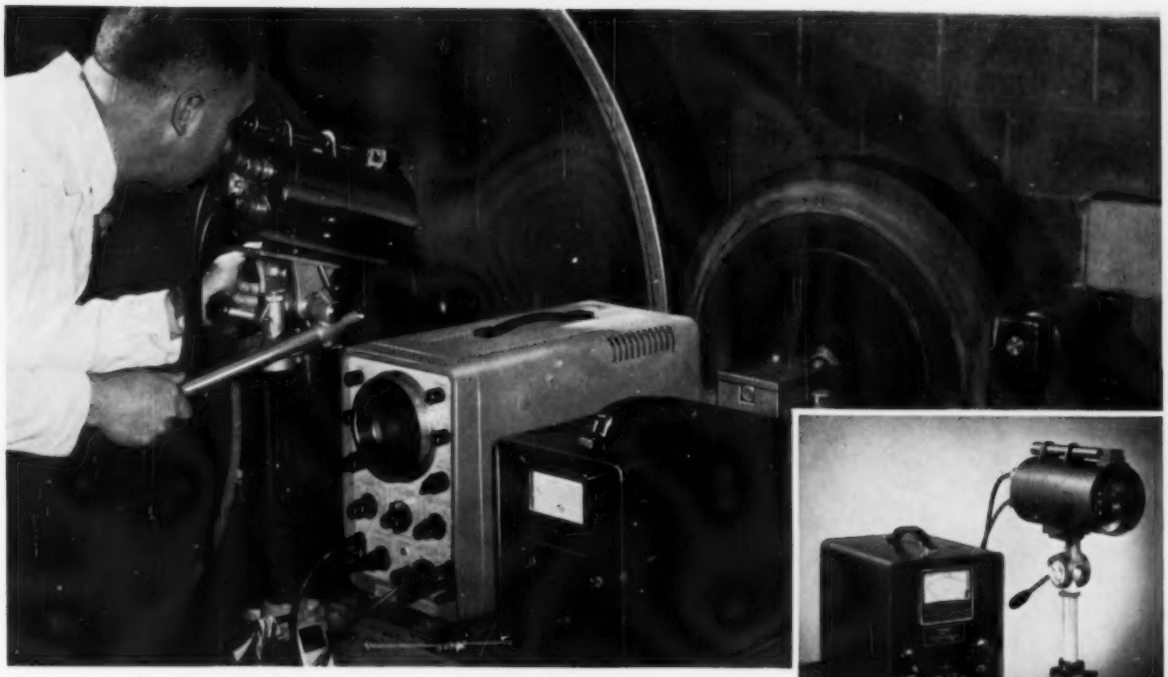

Thermodot radiation thermometer measures temperature of tire, rotating at high speed on test wheel, in Gates Rubber Co. research laboratories at Denver, Colorado.

A Review of INFRARED Detection and Measurement Applications

Infrared systems for military applications, such as missile guidance and satellite reconnaissance, have been well publicized.

Less dramatic, and hence less known, are the recent advances in industrial instrumentation based on infrared technology.

At Radiation Electronics Company, major emphasis has been placed on the development of new infrared components and instruments for industrial purposes. One instrument is the Thermodot radiation thermometer which accurately measures surface temperature without contact. It has a variety of applications in the industrial laboratory and on the production line. The broad temperature range of this instrument (100°F to 8000°F) and response time of two milliseconds, have led to the solution of a number of industrial problems.

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FIBERS. Temperature gradients and cooling rates help identify fiber properties for research and quality control.

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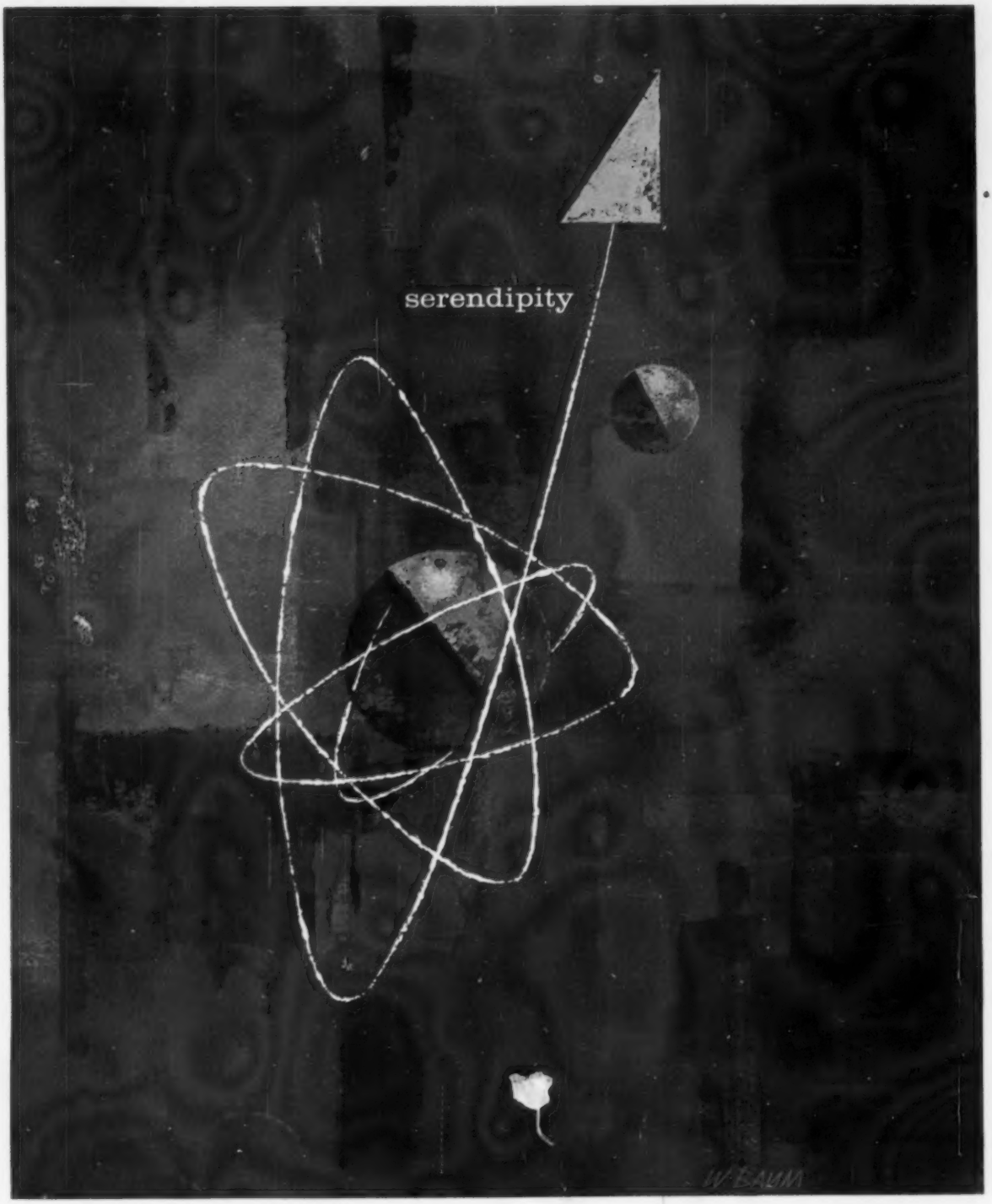

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